# Handbook T-I

## Sustainability in agricultural production and natural resource management

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# ECORFAN Sustainability in agricultural production and natural resource management

Volume I

The Handbook will offer volumes of selected contributions from researchers who contribute to the scientific dissemination activity of the Universidad Politécnica de Francisco I. Madero. in their areas of research in Biotechnology and Agricultural Sciences. In addition to having a total evaluation, in the hands of the directors of the Universidad Politécnica de Francisco I. Madero, the quality and timeliness of its chapters, each individual contribution was refereed to international standards (RESEARCH GATE, MENDELEY, GOOGLE SCHOLAR and REDIB), the Handbook thus proposes to the academic community, recent reports on new developments in the most interesting and promising areas of research in the Biotechnology and Agricultural Sciences.

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# Sustainability in agricultural production and natural resource management T-I
# Biotechnology and Agricultural Sciences
# *Handbooks*

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# Prologue

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This compendium of research papers is a glimpse of the participants that are projected in the handbook on Sustainability in Agricultural Production and Natural Resource Management.

The following pages show the results of projects, research and collective efforts presented at the 1st Inter-University Congress "Sustainability in Agricultural Production and Natural Resource Management and 2nd Inter-University Symposium. Researchers from different institutions of the country share with students, researchers, producers and society in general contents, which with hard dedication, are directed towards the tireless search for knowledge in the field of science.

Each of the disciplines addressed in this handbook within the framework of Aquaculture, Animal Production, Sustainable Agriculture, Pest Management and Sericulture represent a testimony of each author's commitment to the understanding of the various topics covered.

Behind each of the discoveries, there are teams of researchers, brilliant minds committed to the search and expansion of knowledge, whom we thank for being collaborators and creators of this work.

Within these pages, the reader will find innovative research with diverse approaches, which are currently being studied in the agricultural and biological areas in which answers are given to several questions, however, other doubts may arise, with which present and future generations are encouraged to seek knowledge for the sustainable use of natural resources.

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# Chapter 1 Richness and conservation of the birdlife of the municipality of San Felipe Orizatlan, Hidalgo, Mexico

# Capítulo 1 Riqueza y conservación de la avifauna del municipio de San Felipe Orizatlán, Hidalgo, México

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**Abstract**

Between 2020 and 2021, a bird inventory was conducted in the municipality of San Felipe Orizatlán, Hidalgo. A total of 213 bird species were recorded through visual and auditory observations, captures, collections and photographic records. We found 136 resident species, 41 species catalogued as winter visitors, 17 species considered as winter passage visitors, 10 migratory species, nine species are summer visitors and 12 bird species have populations with more than one seasonality category. In the case of 15 species in some category of endemism for Mexico, including four species exclusive to the country. In addition, 28 species were identified in risk categories according to the Mexican Official Standard, three of which are considered in danger of extinction. The analysis of species by vegetation type showed that the greatest richness was found in the secondary vegetation of the medium subperennial rainforest with 126 species, followed by the preserved medium subperennial rainforest with 86 species, riparian vegetation with 83 species, urban areas with 69 species and tropical oak forests with 60 species. In conclusion, the municipality of San Felipe Orizatlán has a high richness of both resident and migratory species that should be protected, especially the sites with relatively conserved vegetation cover that can serve as habitat for species that are in some category of risk.

**Vertebrates, Birds, Inventory, Geographic distribution, Conservation, Ecology, Huasteca region**

**Resumen**

Entre el 2020 y 2021 se realizó un inventario de aves en el municipio de San Felipe Orizatlán, Hidalgo. Se registraron 213 especies de aves mediante observaciones visuales, auditivas, capturas, colectas y registros fotográficos. Se encontraron 136 especies residentes, 41 especies catalogadas como visitantes de invierno, 17 especies consideradas como visitante de invierno de paso, 10 especies migratorias de paso, nueve especies son visitantes de verano y 12 especies de aves tienen poblaciones con más de una categoría de estacionalidad. En el caso de 15 especies en alguna categoría de endemismo para México, incluyendo cuatro especies exclusivas del país. Además, se identificaron 28 especies en categorías de riesgo según la Norma Oficial Mexicana, siendo tres de ellas consideradas en peligro de extinción. El análisis de especies por tipo de vegetación reflejo que la mayor riqueza se presentó en la vegetación secundaria de la selva mediana subperenifolia con 126 especies, seguida por la selva mediana subperenifolia conservada con 86 especies, la vegetación riparia con 83 especies, las zonas urbanas con 69 especies y los bosques de encino tropical con 60 especies. En conclusión, el municipio de San Felipe Orizatlán presenta una alta riqueza de especies tanto residentes como migratorias que debería ser protegida, principalmente los sitios con cobertura vegetal relativamente conservada que pueden servir de hábitat para especies que se encuentran en alguna categoría de riesgo.

**Vertebrados, Aves, Inventario, Distribución geográfica, Conservación, Ecología, Región Huasteca**

## 1 Introduction

Local bird studies are indispensable to broaden knowledge of the geographical distribution, ecology and conservation of this group of vertebrates. Avifaunal inventories in the Neotropics are necessary, as there are still information gaps in many regions, which limits the long-term conservation of birds (Rojas-Soto and Oliveras de Ita, 2005).

In general, the development of avifaunal inventories in Mexico and the Neotropics has been characterised by a notorious lack of continuity (Escalante *et al.*, 1993). Therefore, inventories at a municipal scale can help us to understand the relationships and changes in species richness at a local level within natural environmental heterogeneity, such as between areas with different degrees of disturbance (Villa-Bonilla *et al.*, 2008). Conducting bird inventories at the local level not only contributes to the preservation of biological diversity, but also provides valuable information that can influence decision-making at the community and governmental levels.

In Mexico, several central Mexican states have partial avifaunal inventories, such as Hidalgo, which until 1994 had only 28 studies corresponding to different ornithological topics (Rodríguez-Yánez *et al*., 1994). This has generated a partial knowledge of the areas of greatest bird richness and diversity in this entity (Martínez-Morales *et al*., 2007). However, the potential richness of the Huasteca region, located in the northeastern part of the state of Hidalgo, has not been accurately assessed, resulting in an almost total lack of knowledge of the avifauna in several municipalities in the region (Valencia-Herverth *et al*., 2008).

The purpose of this study is to contribute to the avifaunal knowledge of the Huasteca region, mainly in the municipality of San Felipe Orizatlán, Hidalgo. This will be done by evaluating the richness and abundance of the birds present in the different types of vegetation and land use present in this municipality, which will contribute to future studies so that bird management and conservation plans can be drawn up at the municipal level.

In this context, this paper explores the importance of conducting bird inventories at the municipal level, highlighting their role in biodiversity conservation, promoting sustainable practices and strengthening the connection between communities and their natural environment. A detailed understanding of local avifauna is not only essential for preserving natural heritage, but also contributes to building communities that are more resilient and aware of the importance of caring for the natural heritage they share.

## 1.1 Methodology

### *1.1.1 Study area*

The municipality of San Felipe Orizatlán is located in the northeast of Hidalgo, with a surface area of 3602.7 km2, representing 1.77% of the state's surface area. It is located at 21° 24', 21° 06' north latitude and 98° 28', 98° 42' west longitude. Its altitude ranges from 80 to 660 metres above sea level (INEGI, 2004). The municipality has a semi-warm humid climate with year-round rainfall (A)C(f), with an average annual ambient temperature of 25°C and annual precipitation between 1,200 and 3,000 mm (Hernández-Cerda and Carrasco-Anaya, 2004). The vegetation types present are medium sub-evergreen forest, tropical oak forest (*Quercus* spp.), riparian vegetation (Puig, 1976). In addition, there is a mosaic of secondary vegetation, cattle pasture, agricultural crops and urbanised areas.

### *1.1.2 Field work*

The present research was carried out from March 2020 to November 2021 in 57 sampling points in the municipality of San Felipe Orizatlán, in the northeast of the state of Hidalgo, these areas presented natural vegetation (i.e., medium sub evergreen forest, oak forest, riparian vegetation) and anthropized areas (secondary vegetation, urban vegetation and cattle pasture). The choice of sampling localities was made on the basis of the richness and activity of birds observed with the naked eye. In addition, the degree of conservation of the vegetation type in the area (Fig. 1).

The intensive search census method was used, which consists of carrying out a series of consecutive censuses in different previously known areas, where the observer records the species detected without the strict limitation of the time of day (Villaseñor and Santana, 2003). In addition, it increases the probability of detecting inconspicuous or silent species (Ralph *et al*., 1996). Species detection was carried out by means of visual and auditory records and the collection of specimens. For visual records, 10 x 50 mm binoculars were used, and species identification was carried out with the help of different field guides (Peterson and Chalif, 1989; Howell and Webb, 1995; National Geographic, 2002; Sibley, 2000 and Kaufman, 2005).

To complement the inventory, auditory recordings were used, using bird songs obtained from CDs (Boesman, 2005) to compare and determine the songs of some species that were not observed. Four 3 x 12 m mist nets with 35 mm mesh aperture were used to collect specimens, which were placed in the undergrowth 20 cm above the ground.

*1.2.3 Data analysis*

The systematic listing follows the order proposed by the American Ornithological Society and its latest supplements (Chesser *et al*., 2023). Bird endemism is based on the criteria established by Gonzáles-García and Gómez de Silva (2003), where an endemic species (e) is considered to be one that is only found in Mexico; a quasi-endemic (q) is one whose distribution invades no more than 35,000 $km^2$ into another neighbouring country; a semi-endemic species (s) is considered as such when they are endemic to a country or region during one season of the year. The risk categories were taken from the criteria established in the Norma Oficial Mexicana (SEMARNAT, 2010), and as indicated by the International Union for Conservation of Nature (IUCN, 2023).

The seasonality of the avifauna was determined through literature review following the criteria established by Howell and Webb (1995), whose categories are: breeding resident (R), winter visitor (VI), summer resident (V), winter visitor/migratory passage (IP) and migratory passage (MP). The abundance of the species studied was grouped into three categories: abundant (A) species recorded with more than 15 individuals per month; scarce (E) species not recorded continuously, but with five to 14 individuals observed and rare (R) species not observed in long periods of time with four or less individuals (Coates-Estrada *et al*., 1985; Bojorges, 2004).

Richness by vegetation type (medium sub-evergreen forest, tropical oak forest (*Quercus* spp.), riparian vegetation, secondary vegetation, cattle pasture, agricultural crops and urbanised areas) was determined by considering the site where each species was recorded during the study. Species accumulation models (Herzog *et al*., 2002) were used to determine the degree of completeness of the listing, where all data from systematic sampling plus casual records were considered. Non-parametric estimators such as Jacknife 1 and Bootstrap in EstimateS Ver. 9.1 (Colwell, 2013) were used for this purpose, as they allow the use of presence-absence data and do not assume "a priori" a type of distribution of the dataset (Moreno, 2001). Sampling months served as the unit of effort and the curve was fitted based on 100 random repetitions according to the order of the samples (Colwell and Coddington, 1994), with the results obtained plotting the observed richness and the estimated richness.

## 1.3 Results and discussion

Twenty-two orders, 55 families and 213 species of birds were recorded for the municipality of San Felipe Orizatlán (Appendix 1). The best represented family is Parulidae with 18 species, followed by Icteridae with 16 species, Tyrannidae with 15 species, Ardeidae with 13 species, Accipitridae with 11 species and Cardinalidae with 10 species. According to the non-parametric estimators, between 81% and 90% of the bird species present in the municipality of San Felipe Orizatlán were recorded. According to the Jacknife 1 estimator, 263 species are expected and the Bootstrap estimator estimates the presence of 238 species (Fig. 1.1). The analysis of the sampling data through the species accumulation curve shows that in the first five months more than 50% of the species were recorded, complemented by the months of December and January in which most of the winter visitor species were recorded.

As for species endemic to Mexico, 15 species were found in some category of endemism: four species endemic to Mexico (*Psittacara holochlorus*, *Amazona viridigenalis*, *Momotus coeruliceps*, *Catharus occidentalis*). In addition, six species (*Amazilia yucatanensis*, *Corvus imparatus*, *Toxostoma longirostre*, *Arremonops rufivirgatus*, *Icterus graduacauda*, *Basileuterus rufifrons*) are considered quasi endemic and five species (*Cynanthus latirostris*, *Tyrannus vociferans*, *Vireo cassinii*, *I. cucullatus*, *I. bullockii*) are considered semi endemic. Four introduced species (*Bubulcus ibis*, *Columba livia*, *Streptopelia decaocto*, *Passer domesticus*) were also recorded.

There were 28 species in one of the risk categories in the Official Mexican Standard (SEMARNAT, 2010). Of these, three species (*Cairina moschata*, *Amazona viridigenalis*, *Setophaga chrysoparia*) are considered endangered. Seven species are listed as endangered and 18 species are under special protection criteria under Mexican law. At the international level, two species (*A. viridigenalis* and *S. chrysoparia*) are considered Endangered (EN) and four species (*Colinus virginianus*, *Egretta rufescens*, *Vireo bellii*, *Passerina ciris*) are in the Near Threatened (NT) category, populations of these birds are declining globally and protection measures are urgently needed (IUCN, 2023).

A total of 136 species were recorded as permanent residents, 41 as winter visitors, 17 as winter passage visitors, 10 as passage migrants, nine as summer visitors. In the case of 12 species of birds (*Chaetura vauxi*, *Himantopus mexicanus*, *Ardea alba*, *Egretta thula*, *E. caerulea*, *E. tricolor*, *Buteo jamaicensis*, *Petrochelidon pyrrhonota*, *Polioptila caerulea*, *Troglodytes aedon*, *Molothrus ater*) have populations with different seasonality, so they share some of the categories mentioned, such is the case of *Chaetura vauxi*, which has resident populations and others are winter visitors passing through. *Petrochelidon pyrrhonota* has summer visitor and migratory populations. For eight species (*Ardea alba*, *Egretta caerulea*, *E. thula*, *E. tricolor*, *Buteo jamaicensis*, *Troglodytes aedon*, *Polioptila caerulea*, *Molothrus ater*), they have both resident and winter visitor populations. Species abundance varied widely, with 91 species being rare with abundances of less than four individuals, 50 species were considered scarce and 72 species had high abundances (Appendix 1).

The analysis of species by vegetation type showed that the highest species richness was found in the secondary vegetation of the medium subperennial rainforest with 126 species, followed by the conserved medium subperennial rainforest with 86 species, riparian vegetation with 83 species, urban areas with 69 species and tropical oak forests with 60 species. Livestock pastures and agricultural crops had similar species richness (48 and 46 species, respectively), with the secondary vegetation of oak forests having the lowest number of species with only 21. Most of the vegetation cover present in the municipality is under different degrees of disturbance, which has generated a mosaic of medium-sized forest fragments and regenerating secondary vegetation, the latter being the ones that contribute the most species to this study (Fig. 1.2). Taking into account the exclusivity that many species have to the different habitats, this varied greatly, with riparian vegetation representing a very high exclusivity with 23 species, followed by the secondary vegetation of the medium-sized forest with 13 species and the oak forests with 10 species (Fig. 1.2).

## 1.4 Conclusions

The study conducted in the municipality of San Felipe Orizatlán has provided valuable information on avifaunal diversity in the region. With a total of 213 species recorded, it is estimated that between 81% and 90% of the avifauna present in the area has been covered according to the Jacknife 1 and Bootstrap estimators. In this municipality there is evidence that 42.5% of birds recorded for the state of Hidalgo (Ortiz-Pulido and Zuria, 2017) may be present at some time of the year. For the first time, 183 bird species are recorded for the municipality of San Felipe Orizatlán, as there was only evidence of 30 species in a partial inventory published in 1977 (Bjelland and Ray, 1977).

Of note is the presence of 15 species in some category of endemism for Mexico, including four species exclusive to the country (*Psittacara holochlorus*, *Amazona viridigenalis*, *Momotus coeruliceps*, *Catharus occidentalis*). In addition, 28 species were identified in risk categories according to the Mexican Official Standard, three of which are considered endangered. At the international level, two species are in the Endangered category and four in the Near Threatened category.

The temporal distribution of the birds reveals that the dynamics of the avifauna changed according to the seasons of the year, with a higher proportion of resident birds with 61% (136 species). The 41 species catalogued as winter visitors reveal the strong seasonal influence on the local avifauna. These birds find temporary refuge in the municipality during the colder months, and the presence of these species not only increases the diversity observed, but also acts as an indicator of the health of the ecosystem, the quality of the environment and the resources available in relation to the seasons of the year (Díaz-Bohórquez *et al*., 2021).

The 10 migratory passage species (*Coccyzus americanus*, *Archilochus colubris*, *Pluvialis dominica*, *Ictinia mississippiensis*, *Tyrannus forficatus*, *Vireo olivaceus*, *Petrochelidon pyrrhonota*, *Icterus spurius*, *Setophaga chrysoparia*, *Piranga olivacea*) underline the importance of the municipality in the global network of bird habitats. These birds use the region as a stopover point on their migratory journeys, highlighting the relevance of maintaining healthy ecosystems and migratory corridors to ensure the success of these annual movements (Cotton *et al*., 2009). The recording of these species is not only a testament to the connectivity of habitats globally, but also a call to action to conserve and protect these essential corridors.

The presence of nine species listed as summer visitors (*Cypseloides niger*, *Anthracothorax prevostii*, *Ictinia plumbea*, *Myiodynastes luteiventris*, *Legatus leucophaius*, *Progne chalybea*, *Hirundo rustica*, *Petrochelidon pyrrhonota*, *Cyanerpes cyaneus*) suggests that the municipality serves as a temporary habitat for birds that take advantage of the resources available during the warm season. This phenomenon not only contributes to the diversity of species observed but may also have important implications in terms of the genetic diversity and adaptability of local populations.

Overall, the diversity of migratory birds in this inventory not only expands the list of species recorded, but also highlights the need to consider movement dynamics and habitat interconnectedness in conservation efforts at the municipal and regional levels. The study area incurs a high degree of migratory birds at different times of the year (Cotton *et al*., 2009), so it is essential to conserve the potential sites where these birds arrive, which not only benefits the migratory birds themselves, but also enriches and strengthens the local ecosystem.

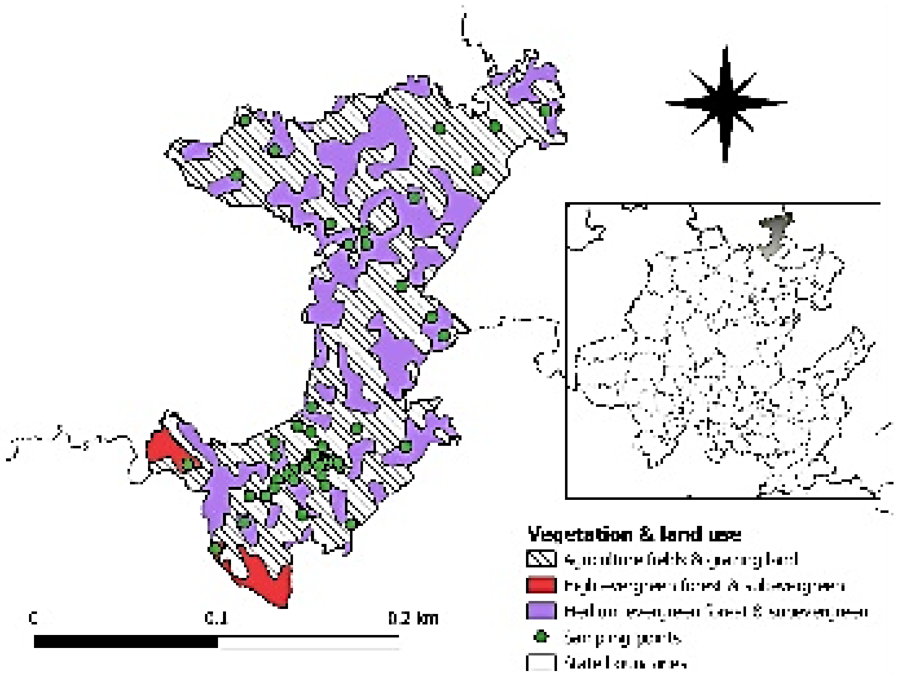
In summary, the detailed analysis of species according to vegetation type clearly reveals the close relationship between avifaunal richness and habitat diversity in the area studied (Sáenz *et al*., 2006). The preservation of the secondary vegetation of the subperennial medium rainforest and the preserved subperennial medium rainforest is a priority to maintain the biodiversity of both resident and migratory birds in this region (Rappole, 1983). The significant presence of species in urban areas also underlines the importance of considering conservation strategies in anthropogenic environments (Bautista-Trejo *et al*., 2023). This suggests the need to implement measures to mitigate the negative impacts of urbanisation on natural habitats and to foster harmonious coexistence between birds and human communities (Barragán and Silva, 2023).

Riparian vegetation, or riverine vegetation, emphasises its importance as an ecological corridor and vital habitat for a wide variety of birds. These riparian environments often provide a unique combination of resources, such as food, shelter and breeding sites, which attract diverse bird species (Ruvalcaba-Ortega *et al*., 2008; Balderas-SanMiguel et al., 2020). In this habitat 83 bird species were recorded, which could play a fundamental role in the conservation of aquatic and water body-associated species such as birds belonging to the families Anatidae, Podicipedidae, Rallidae, Recurvirostridae, Charadriidae, Jacanidae, Scolopacidae, Laridae, Ciconiidae, Anhingidae, Phalacrocoracidae, Pelecanidae, Ardeidae, Threskiornithidae and Alcedinidae. As these areas often harbour aquatic ecosystems such as rivers and streams, they can be essential for birds that depend on these specific habitats for their subsistence, being a refuge for 38 species were migratory in this area. The connectivity offered by these riparian areas can facilitate bird migration and promote interaction between populations, thus contributing to genetic health and population dynamics (Ruvalcaba-Ortega *et al*., 2008). Riparian vegetation is a valuable component of the landscape, contributing significantly to the richness of bird species in the municipality. Its conservation and sustainable management are necessary to ensure the preservation of biological diversity and the healthy functioning of aquatic ecosystems, as well as to maintain connectivity between different habitats.

These results underline the importance of conserving and protecting different habitats used by birds in San Felipe Orizatlán, especially for those species at risk of extinction. The study provides a solid basis for future research and conservation actions, contributing to the understanding and preservation of the rich avian biodiversity in the region. In conclusion, the municipality of San Felipe Orizatlán has a high richness of both resident and migratory species that should be protected, mainly sites with relatively conserved vegetation cover that can serve as habitat for species that are in some category of risk such as *Cairina moschata*, *Amazona viridigenalis* and *Setophaga chrysoparia* that are considered endangered and require protection of their populations at the local level.

**1.5 Annexes**

**Figure 1** Geographical location of the study area, indicating the sampling points and vegetation type in the municipality of San Felipe Orizatlán




*Source: own elaboration*

**Figure 1.1** Bird species accumulation curves for the municipality of San Felipe Orizatlán. Data are presented for observed and expected species from two species accumulation models (Jacknife 1 and Bootstrap 1)

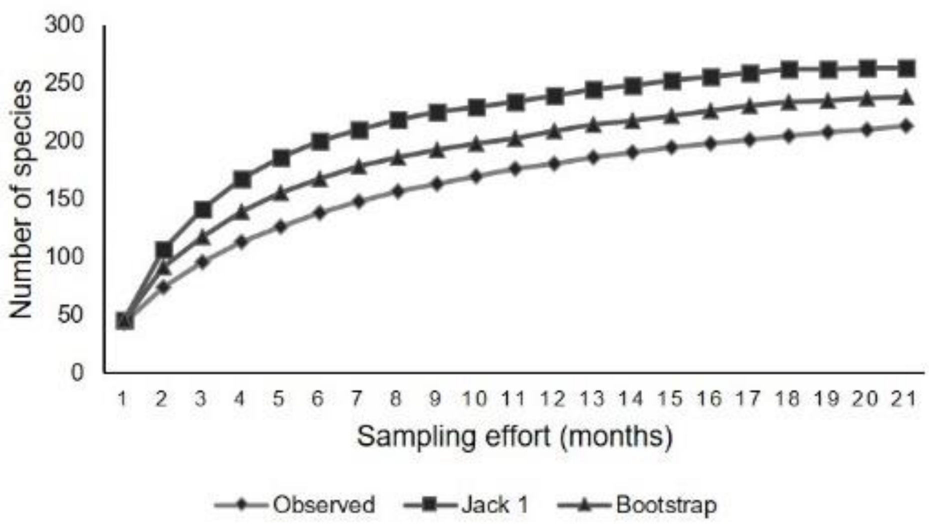
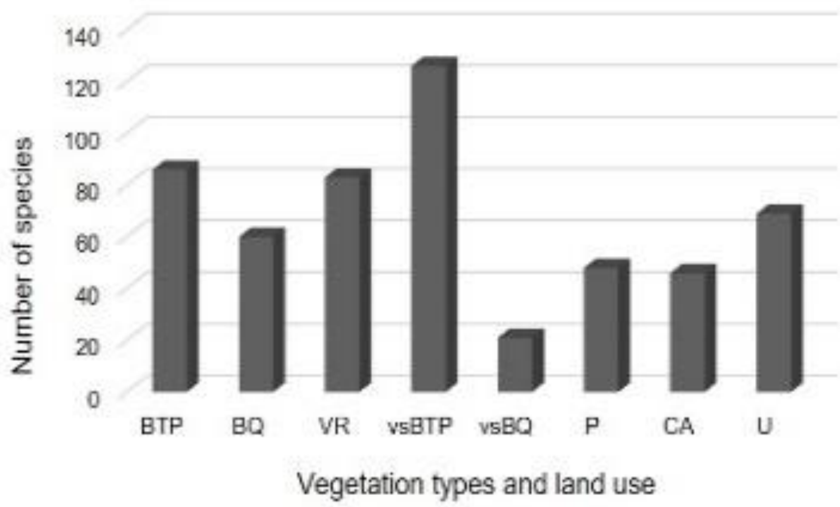


**Figure 1.2** Number of bird species recorded by vegetation type and land use in the municipality of San Felipe Orizatlán, Hidalgo




**Appendix I.** Bird species present in the municipality of San Felipe Orizatlán, Hidalgo, Mexico. Indicated for each species are relative abundance (Abundant, Scarce and Rare), seasonality (R = resident, V = summer visitor, VI = winter visitor, IP = winter visitor/migratory passage, MP = migratory passage), distribution type (E = endemic, CS = quasi endemic, SE = semi endemic, I = exotic-invasive), risk category (P = endangered, A = threatened, Pr = subject to special protection), vegetation or land use type (B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, B = vegetation or land use type, A = threatened, Pr = subject to special protection), vegetation type or land use (BTP = tropical evergreen forest, BQ = Quercus forest, VR = riparian vegetation, vsBTP = tropical evergreen forest secondary vegetation, vsBQ = Quercus forest secondary vegetation, P = livestock grazing, CA = agricultural crops, U = urban area).

| Species | ABU | EST | TD | NOM | Type of vegetation/land use |
|---|---|---|---|---|---|
| **TINAMIFORMES** | | | | | |
| **Tinamidae** | | | | | |
| *Crypturellus cinnamomeus* | Es | R | | Pr | BT, VST |
| **ANSERIFORMES** | | | | | |
| **Anatidae** | | | | | |
| *Dendrocygna autumnalis* | A | R | | | VR |
| *Cairina moschata* | Es | R | | P | VR, BT |
| *Aix sponsa* | Es | VI | | | VR |
| *Spatula discors* | A | VI | | | VR |
| *Anas fulvigula* | R | VI | | A | VR |
| *Anas crecca* | R | VI | | | VR |
| **GALLIFORMES** | | | | | |
| **Cracidae** | | | | | |
| *Ortalis vetula* | A | R | | | BT, VST |
| **Odontophoridae** | | | | | |
| *Colinus virginianus* | A | R | | | VST, P |
| **PODICIPEDIFORMES** | | | | | |
| **Podicipedidae** | | | | | |
| *Tachybaptus dominicus* | Es | R | | Pr | VR |
| *Podilymbus podiceps* | Es | R | | | VR |
| **COLUMBIFORMES** | | | | | |
| **Columbidae** | | | | | |
| *Columba livia* | A | R | In | | U |
| *Patagioenas flavirostris* | A | R | | | BT, BQ |
| *Streptopelia decaocto* | Es | R | In | | U |
| *Columbina inca* | Es | R | | | BT, BQ, VST, VSQ, CA, U |
| *Columbina passerina* | Es | R | | | VST, CA |
| *Columbina talpacoti* | A | R | | | VR, VST, P, CA |
| *Geotrygon montana* | Es | R | | | BT, BQ, VST, VSQ |
| *Leptotila verreauxi* | A | R | | | BQ, VR, VST, P |
| *Zenaida asiatica* | A | R | | | BT, BQ, VST, P, CA, U |

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| **CUCULIFORMES** | | | | | |
| **Cuculidae** | | | | | |
| *Crotophaga sulcirostris* | A | R | | | BQ, VR, VST, P |
| *Piaya cayana* | A | R | | | BT, BQ, VR, VST, P, CA |
| *Coccyzus americanus* | R | MP | | | BQ |
| **CAPRIMULGIFORMES** | | | | | |
| **Caprimulgidae** | | | | | |
| *Chordeiles minor* | R | MP | | | BT, VST |
| *Nyctidromus albicollis* | Es | R | | | VR, VST |
| **APODIFORMES** | | | | | |
| **Apodidae** | | | | | |
| *Cypseloides niger* | Es | V | | | VST |
| *Chaetura vauxi* | Es | R, IP | | | VR, U |
| **Trochilidae** | | | | | |
| *Anthracothorax prevostii* | Es | V | | | BT, VST, U |
| *Archilochus colubris* | Es | MP | | | BQ, U |
| *Cynanthus latirostris* | Es | R | SE | | BT, VR, VST, U |
| *Cynanthus canivetii* | A | R | | | BT, VST, U |
| *Pampa curvipennis* | A | R | | | BT, VST, U |
| *Amazilia yucatanensis* | A | R | CE | | BT, BQ, VR, VST, VSQ, U |
| **GRUIFORMES** | | | | | |
| **Rallidae** | | | | | |
| *Aramides albiventris* | R | R | | | VR |
| *Gallinula galeata* | R | R | | | VR, P |
| *Fulica americana* | Es | R | | | VR, P |
| *Porphyrio martinicus* | R | R | | | VR, P |
| **CHARADRIIFORMES** | | | | | |
| **Recurvirostridae** | | | | | |
| *Himantopus mexicanus* | R | R, IP | | | VR, P |
| **Charadriidae** | | | | | |
| *Pluvialis dominica* | R | MP | | | VR |
| *Charadrius vociferus* | A | R | | | VR, VST P |
| **Jacanidae** | | | | | |
| *Jacana spinosa* | A | R | | | VR, VST, P |
| **Scolopacidae** | | | | | |
| *Gallinago delicata* | A | VI | | | VR, P |
| *Actitis macularius* | A | IP | | | BT, VST, VR, P |
| *Tringa semipalmata* | R | IP | | | VR |
| **Laridae** | | | | | |
| *Leucophaeus atricilla* | R | VI | | | VR |
| *Larus argentatus* | R | VI | | | BQ, VR, VSQ, U |
| **CICONIIFORMES** | | | | | |
| **Ciconiidae** | | | | | |
| *Mycteria americana* | R | VI | | Pr | VR, P |
| **SULIFORMES** | | | | | |
| **Anhingidae** | | | | | |
| *Anhinga anhinga* | R | R | | | VR |
| **Phalacrocoracidae** | | | | | |
| *Nonnopterum auritus* | R | VI | | | VR |
| *Nonnopterum brasilianus* | A | R | | | BT, VR, P |
| **PELECANIFORMES** | | | | | |
| **Pelecanidae** | | | | | |
| *Pelecanus erythrorhynchos* | R | VI | | | VR |
| **Ardeidae** | | | | | |
| *Botaurus lentiginosus* | R | VI | | A | VR, VST |
| *Tigrisoma mexicanum* | Es | R | | Pr | BT, VR |
| *Ardea herodias* | R | VI | | | VR |
| *Ardea alba* | A | R, VI | | | VR, P |
| *Egretta thula* | A | R, VI | | | BT, VR |
| *Egretta caerulea* | A | R, VI | | | BT, VR, VST |
| *Egretta tricolor* | R | R, VI | | | VR, VST, U |
| *Egretta rufescens* | R | R | | Pr | VR, P |
| *Bubulcus ibis* | A | R | In | | VR, P, U |
| *Butorides virescens* | A | R | | | BT, BQ, VR, VST, U |
| *Nycticorax nycticorax* | R | R | | | VR |
| *Nyctanassa violacea* | R | R | | | VR |
| *Cochlearius cochlearius* | E | R | | | VR, VST |
| **Threskiornithidae** | | | | | |
| *Eudocimus albus* | A | VI | | | BT, VR, VST, P |
| *Plegadis chihi* | A | VI | | | BT, VR, CA, P |

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| *Platalea ajaja* | R | VI | | | VR, P |
| **CATHARTIFORMES** | | | | | |
| **Cathartidae** | | | | | |
| *Coragyps atratus* | A | R | | | BT, BQ, VR, VST, VSQ, CA, P, U |
| *Cathartes aura* | A | R | | | BT, BQ, VST |
| **ACCIPITRIFORMES** | | | | | |
| **Accipitridae** | | | | | |
| *Accipiter cooperii* | R | VI | | Pr | VST, U |
| *Ictinia mississippiensis* | R | MP | | Pr | VST, U |
| *Ictinia plumbea* | R | V | | Pr | BQ |
| *Geranospiza caerulescens* | R | R | | A | BQ |
| *Buteogallus anthracinus* | Es | R | | Pr | BT, BQ, VST |
| *Rupornis magnirostris* | A | R | | | BT, BQ, VR, VST, VSQ, CA |
| *Parabuteo unicinctus* | R | R | | Pr | CA, U |
| *Buteo lineatus* | R | VI | | Pr | BQ, U |
| *Buteo plagiatus* | E | R | | | BT, BQ, VR, VST, VSQ |
| *Buteo brachyurus* | R | R | | | BT, VST, U |
| *Buteo jamaicensis* | R | R, VI | | | P |
| **STRIGIFORMES** | | | | | |
| **Tytonidae** | | | | | |
| *Tyto alba* | R | R | | | VST, U |
| **Strigidae** | | | | | |
| *Glaucidium brasilianum* | Es | R | | | BT, VST, CA |
| *Strix virgata* | Es | R | | | BT, VST, CA, U |
| **TROGONIFORMES** | | | | | |
| **Trogonidae** | | | | | |
| *Trogon elegans* | R | R | | | BT |
| *Trogon collaris* | R | R | | Pr | BQ |
| **CORACIIFORMES** | | | | | |
| **Momotidae** | | | | | |
| *Momotus coeruliceps* | A | R | E | | BT, VST, VR |
| **Alcedinidae** | | | | | |
| *Megaceryle torquata* | A | R | | | VR |
| *Chloroceryle amazona* | Es | R | | | VR |
| *Chloroceryle americana* | A | R | | | VR |
| **PICIFORMES** | | | | | |
| **Picidae** | | | | | |
| *Melanerpes formicivorus* | A | R | | | BQ, VSQ, VST |
| *Melanerpes aurifrons* | A | R | | | BT, BQ, VST, CA, U |
| *Dryocopus lineatus* | Es | R | | | BT, BQ, VSQ, CA |
| *Campephilus guatemalensis* | R | R | | Pr | BT |
| **FALCONIFORMES** | | | | | |
| **Falconidae** | | | | | |
| *Herpetotheres cachinnans* | R | R | | | BT, VR |
| *Micrastur semitorquatus* | R | R | | Pr | BT, VST |
| *Caracara plancus* | A | R | | | BT, VR, VST, VSQ, P |
| *Falco sparverius* | Es | IP | | | VST, CA, P |
| *Falco femoralis* | R | R | | A | BT |
| *Falco rufigularis* | R | R | | | BT, U |
| **PSITTACIFORMES** | | | | | |
| **Psittacidae** | | | | | |
| *Psittacara holochlorus* | A | R | E | A | BT, VR |
| *Pionus senilis* | R | R | | A | BT, VST |
| *Amazona viridigenalis* | Es | R | E | P | BQ, VST |
| *Amazona autumnalis* | A | R | | | BT, BQ |
| **PASSERIFORMES** | | | | | |
| **Tytiridae** | | | | | |
| *Tityra semifasciata* | A | R | | | BT, VR, VST |
| *Pachyramphus major* | R | R | | | VST |
| *Pachyramphus aglaiae* | Es | R | | | BT, BQ, VST |
| **Tyrannidae** | | | | | |
| *Myiarchus tuberculifer* | Es | R | | | BT, VST, VSQ, CA |
| *Myiarchus tyrannulus* | Es | R | | | BT, BQ, VST |
| *Pitangus sulphuratus* | A | R | | | BT, VR, VST, CA, P |
| *Megarynchus pitangua* | Es | R | | | VST |
| *Myiozetetes similis* | A | R | | | BT, VR, VST, VSQ |
| *Myiodynastes luteiventris* | R | V | | | BQ, VR |
| *Legatus leucophaius* | R | V | | | BQ |
| *Tyrannus melancholicus* | A | R | | | VST, P |
| *Tyrannus vociferans* | R | R | SE | | CA, P |

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| *Tyrannus forficatus* | R | MP | | | BT |
| *Empidonax minimus* | Es | VI | | | BQ, VR, VST, CA |
| *Sayornis nigricans* | R | R | | | VR |
| *Sayornis phoebe* | Es | IP | | | BT, VR, VST, VSQ, CA, P, U |
| *Sayornis saya* | R | VI | | | VR, VST, CA |
| *Pyrocephalus rubinus* | A | VI | | | BT, BQ, VR, VST, CA, P, U |
| **Thamnophilidae** | | | | | |
| *Thamnophilus doliatus* | R | R | | | BQ, VST |
| **Furnariidae** | | | | | |
| *Xiphorhynchus flavigaster* | R | R | | | BT |
| **Vireonidae** | | | | | |
| *Cyclarhis gujanensis* | R | R | | | VST |
| *Vireo griseus* | R | R | | | BQ, VST |
| *Vireo bellii* | R | IP | | | VST, U |
| *Vireo huttoni* | R | R | | | VST |
| *Vireo flavifrons* | R | IP | | | VST |
| *Vireo cassinii* | R | VI | SE | | VST |
| *Vireo solitarius* | R | IP | | | BQ, VSQ, P |
| *Vireo olivaceus* | R | MP | | | VST |
| **Corvidae** | | | | | |
| *Psilorhinus morio* | A | R | | | BT, BQ, VR, VST, VSQ, CA, P |
| *Cyanocorax yncas* | A | R | | | BT, VST, U |
| *Corvus imparatus* | Es | R | CE | | P, U |
| *Corvus cryptoleucus* | R | VI | | | U |
| **Paridae** | | | | | |
| *Baeolophus atricristatus* | A | R | | | BT, BQ, VST |
| **Hirundinidae** | | | | | |
| *Tachycineta bicolor* | Es | VI | | | BT, VST, U |
| *Tachycineta albilinea* | R | R | | | VR |
| *Stelgidopteryx serripennis* | A | R | | | VR, VST, CA |
| *Progne chalybea* | R | V | | | VST, U |
| *Hirundo rustica* | A | V | | | VST, CA, U |
| *Petrochelidon pyrrhonota* | R | V, MP | | | U |
| **Regulidae** | | | | | |
| *Regulus calendula* | A | VI | | | VR, U |
| **Bombycillidae** | | | | | |
| *Bombycilla cedrorum* | Es | IP | | | VR, VST |
| **Ptiliogonatidae** | | | | | |
| *Phainopepla nitens* | R | R | | | VST |
| **Polioptilidae** | | | | | |
| *Polioptila caerulea* | A | R, VI | | | BT, BQ, VR, VST, CA |
| **Troglodytidae** | | | | | |
| *Pheugopedius maculipectus* | E | R | | | BQ, VST |
| *Henicorhina leucosticta* | R | R | | | BT, VST |
| *Campylorhynchus zonatus* | A | R | | | BQ, VST, U |
| *Troglodytes aedon* | R | R, VI | | | VST |
| **Mimidae** | | | | | |
| *Dumetella carolinensis* | A | IP | | | BT, BQ, VST, CA |
| *Toxostoma longirostre* | R | R | CE | | BQ |
| *Mimus polyglottos* | Es | R | | | BT, VR, VST, CA, P |
| **Turdidae** | | | | | |
| *Myadestes occidentalis* | Es | R | | Pr | BT |
| *Catharus occidentalis* | R | R | E | | BT |
| *Turdus grayi* | A | R | | | BT, VR, VST, VSQ, CA, U |
| **Passeridae** | | | | | |
| *Passer domesticus* | A | R | In | | U |
| **Fringillidae** | | | | | |
| *Euphonia affinis* | A | R | | | BT, VST, U |
| *Euphonia hirundinacea* | A | R | | | BT, VR, VST, U |
| *Haemorhous mexicanus* | R | R | | | VST |
| **Passerellidae** | | | | | |
| *Arremonops rufivirgatus* | A | R | CE | | BQ, VST, VSQ, U |
| **Icteriidae** | | | | | |
| *Icteria virens* | R | IP | | | CA, U |
| **Icteridae** | | | | | |
| *Xanthocephalus xanthocephalus* | R | VI | | | VST, VSQ |
| *Sturnella magna* | R | R | | | VST, P |
| *Amblycercus holosericeus* | R | R | | | VST, P |
| *Psarocolius montezuma* | A | R | | Pr | BT, BQ, VR, VST |
| *Icterus wagleri* | R | R | | | VST |

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| *Icterus spurius* | R | MP | | | BQ, CA |
| *Icterus cucullatus* | A | R | SE | | BT, VST, P, CA, U |
| *Icterus bullockii* | R | VI | SE | | VST |
| *Icterus gularis* | A | R | | | BT, BQ, VST, P, CA, U |
| *Icterus graduacauda* | R | R | CE | | BQ |
| *Icterus galbula* | R | VI | | | VST, CA, U |
| *Agelaius phoeniceus* | R | R | | | VR |
| *Molothrus aeneus* | A | R | | | BT, VST, CA, P, U |
| *Molothrus ater* | A | R, VI | | | CA, P, U |
| *Dives dives* | A | R | | | VST, VSQ, P, CA |
| *Quiscalus mexicanus* | A | R | | | BT, BQ, VR, VST, VSQ, P, CA, U |
| **Parulidae** | | | | | |
| *Seiurus aurocapilla* | Es | VI | | | U |
| *Vermivora cyanoptera* | R | IP | | | BQ |
| *Mniotilta varia* | A | VI | | | BT, BQ, VST, CA, U |
| *Leiothlypis peregrina* | R | IP | | | U |
| *Leiothlypis celata* | Es | VI | | | U |
| *Geothlypis tolmiei* | R | VI | | A | VST, U |
| *Geothlypis trichas* | R | VI | | | BQ, VST, U |
| *Setophaga citrina* | R | IP | | | BT, BQ |
| *Setophaga ruticilla* | Es | IP | | | BQ, VST, CA |
| *Setophaga magnolia* | R | VI | | | VST, U |
| *Setophaga petechia* | R | IP | | | BQ |
| *Setophaga dominica* | A | IP | | | BT, BQ, U |
| *Setophaga townsendi* | R | VI | | | VST, U |
| *Setophaga chrysoparia* | R | MP | | P | BQ, VST |
| *Setophaga virens* | A | VI | | | BT, BQ, VST, CA, U |
| *Basileuterus rufifrons* | R | R | CE | | BQ |
| *Basileuterus culicivorus* | Es | R | | | BT, VST, CA, U |
| *Cardellina pusilla* | A | VI | | | BT, BQ, VR, VST, CA, P, U |
| **Cardinalidae** | | | | | |
| *Piranga rubra* | Es | VI | | | BT, BQ |
| *Piranga olivacea* | R | MP | | | BT, VST |
| *Piranga ludoviciana* | Es | IP | | | BT |
| *Habia fuscicauda* | R | R | | | BT, VST |
| *Cardinalis cardinalis* | R | R | | | VST, P |
| *Pheucticus ludovicianus* | Es | VI | | | VST, U |
| *Cyanocompsa parellina* | Es | R | | | VST, U |
| *Passerina caerulea* | R | VI | | | VST, U |
| *Passerina cyanea* | R | VI | | | VST, P |
| *Passerina ciris* | Es | VI | | Pr | VST, VSQ, U |
| **Thraupidae** | | | | | |
| *Thraupis episcopus* | A | R | | | VST, CA, U |
| *Thraupis abbas* | A | R | | | BT, VR, VST, CA, U |
| *Volatinia jacarina* | A | R | | | BT, VST, CA |
| *Cyanerpes cyaneus* | R | R, V | | | BT, VST, U |
| *Tiaris olivaceus* | Es | R | | | VST, VSQ, P |
| *Sporophila torqueola* | A | R | | | VR, VST, CA, P, U |
| *Saltator atriceps* | A | R | | | BT, BQ, VST, P |

## 1.6 References


Arizmendi, M. C., & Márquez-Valdelamar, L. (ed.). (2000). *Áreas de importancia para la conservación de las aves en México (AICA)*. CIPAMEX; Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México. D.F.

Balderas-San Miguel, O., Alcántara-Salinas, G., Rivera-Hernández, J. E., Román-Hernández, D., & Vargas-Rueda, A. F. (2020). Las aves como elementos importantes del turismo de naturaleza en un bosque ribereño de Veracruz, México. *Revista Environment & Technology*, 1(1), 6-22. DOI: https://doi.org/10.56205/ret.1-1.1

Barragán Mayet, K. F., & Silva Castillo, R.O. (2023). Importancia ecológica, interacción y acciones civiles en la convivencia con especies de fauna silvestre urbanas. *Revista Medica Veterinaria*, 46(1): e1448. DOI: https://doi.org/10.19052/mv.vol1.iss46.12

Bautista-Trejo, R., Ramírez-Hernández, M., Gómez-Garduño, J.O., Valverde-Nieto, J.G., Cayetano-Rosas, H., Piñón-Santoyo, N., Cabañas-Pérez, J.P., Ramírez-Albores, J.E. (2023). Aves del Parque Estatal Ecológico, Turístico y Recreativo Sierra Hermosa, Estado de México. *Ecosistemas y Recursos Agropecuarios*, 10(3):e3747. DOI: https://doi.org/10.19136/era.a10n3.3747

Bjelland, A. D., & Ray, J. C. (1977). Birds collected in the state of Hidalgo, Mexico. *Occasional Papers, Museum of Texas Tech University*, 46,1-32. https://www.depts.ttu.edu/nsrl/publications/downloads/OP46.pdf

Boesman, P. (2005). *Birds of México, MP3 sound collection*. Birdsounds.nl. Hoofdstraat W. 14, NL-9951 AB Winsum (GM), The Netherlands.

Chesser, R. T., Billerman, S. M., Burns, K. J., Cicero, C., Dunn, J. L., Hernández-Baños, B. E., Jiménez, R. A., Kratter, A. W., Mason, N. A., Rasmussen, P. C., Remsen Jr., J. V., & Winker, K. (2023). *Check-list of North American Birds* (online). American Ornithological Society. https://checklist.americanornithology.org/taxa/

Colwell, R. K. (2005). *EstimateS: statistical estimation of species richness and shared species from samples. Version 7.5. Guía del usuario y aplicación*. http://viceroy.eeb.uconn.edu/estimates

Colwell, R. K., & Coddington, J. A. (1994). Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 345, 101-118. DOI: https://doi.org/10.1098/rstb.1994.0091

Cotton, K., Fry, M., Holmer, S., King, A., Schroeder, D., & Shire, G. (2009). *Saving migratory birds for future generations: the success of the Neotropical migratory bird conservation act*. American Bird Conservatory. Washington, DC. https://abcbirds.org/wp-content/uploads/2015/05/act_songbirds.pdf

Díaz-Bohórquez, A. M., Bayly, N. J., Botero, J. E., & Gómez, C. (2021). Aves migratorias en agroecosistemas del norte de Latinoamérica, con énfasis en Colombia: Migratory birds in northern Latin American agroecosystems with emphasis on Colombia. *Ornitología Colombiana*, (14), 3–27. https://asociacioncolombianadeornitologia.org/ojs/index.php/roc/article/view/351

Escalante, P., Navarro, A. G., & Peterson. A. T. (1998). Un análisis geográfico, ecológico e histórico de la diversidad de aves terrestres de México. Pp. 279-304. *In*: Ramammoorthy, T. P., Bye, R., Lot, A., & Fa, J. (Eds.), *Diversidad biológica de México: orígenes y distribución*. Instituto de Biología, UNAM, México, D.F.

González-García, F., & Gómez-de Silva, H. (2003). Especies endémicas: riqueza patrones de distribución y retos para su conservación. Pp. 150–194. *In*: Gómez-de Silva, H. & Oliveras-de Ita, A. (Eds.), *Conservación de aves. Experiencias en México*. México, D.F.: CIPAMEX, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, National Fish and Wildlife Foundation. https://www.researchgate.net/publication/265466602_Especies_endemicas_riqueza_patrones_de_distribucion_y_retos_para_su_conservacion

Hernández-Cerda, M. E., & Carrasco-Anaya, G. (2004). Climatología. Pp. 63- 108. *In*: Luna, I., Morrone, J. J. & Espinosa, D. (Eds.), *Biodiversidad de la Sierra Madre Oriental*. Las Prensas de la Ciencia. Facultad de Ciencias, UNAM, México, D. F.

Herzog, S. K., Kessler, M., & Cahill, T. M. (2002). Estimating species richness of tropical bird communities from rapid assessment data. *The Auk*, 119(3), 749-769. DOI: https://doi.org/10.1093/auk/119.3.749

Howell, S. N. G., & Webb, S. (1995). *A guide to the birds of Mexico and northern Central America*. Oxford University Press, Oxford.

Instituto Nacional de Estadística y Geografía (INEGI). (2004). *Anuario estadístico del estado de Hidalgo*. INEGI, Aguascalientes, México.

International Union for Conservation of Nature (IUCN). (2023). *The IUCN Red List of Threatened Species. Version 2023-1*. https://www.iucnredlist.org

Kaufman, K. (2005). *Guía de campo a las aves de Norteamérica*. Houghton Mifflin Company, New York, EUA. 392p.

Martínez-Morales, M.A., Ortiz-Pulido, R., de la Barreda, B., Zuria, I.L. Bravo-Cadena, J. y Valencia-Herverth, J. (2007). HIDALGO. Pp. 49-95. *In*: Ortiz-Pulido, R., Navarro-Sigüenza, A., Gómez de Silva, H., Rojas-Soto, O. y Peterson, T.A. (Eds.), *Avifaunas Estatales de México*. CIPAMEX. Pachuca, Hidalgo, México. https://cipaexdotorg.files.wordpress.com/2020/04/2007_avifaunas-estatales-hidalgo.pdf

Miranda, F. & Hernández-X, E. (1963). Los tipos de vegetación en México y su clasificación. *Boletín de la Sociedad Botánica de México*, 28, 29-179. https://doi.org/10.17129/botsci.1084

Moreno, C. E. (2001). *Métodos para medir la biodiversidad.* M&T-Manuales y Tesis SEA, vol. I. Zaragoza, España, 84 pp. http://entomologia.rediris.es/sea/manytes/metodos.pdf

National Geographic Society. (2002). *Field guide to the birds of North America*. Fourth edition. National Geographic Society, Washington, D.C. USA, 480 p.

Ortiz-Pulido, R., & Zuria, I. (2017). Diversidad de aves del estado de Hidalgo. Pp. 529–557. In: A. Ramírez-Bautista, A. Sánchez-González, G. Sánchez-Rojas y C. Cuevas-Cardona (Eds.), *Biodiversidad del estado de Hidalgo. Tomo II*. Pachuca: Universidad Autónoma del Estado de Hidalgo; Consejo Nacional de Ciencia y Tecnología.

Peterson, R. T., & Chalif, E. L. (1989). *Aves de México, Guía de Campo*. Editorial Diana, México, D.F. 473 p.

Puig, H. (1976). *Végétation de la Huasteca, Mexique*. Misión Archéologica et Ethologique Française au Mexique, México, D. F. 531 p.

Ralph, C. J., Geupel, G. R., Pyle, P., Martin, T. E., DeSante, D. F., & Milá, B. (1996). *Manual de métodos de campo para el monitoreo de aves terrestres*. General Technical Report. PSW-GTR-159. Pacific Southwest Research Station. Forest Service, U.S. Department of Agriculture. Albany, California. DOI: https://doi.org/10.2737/PSW-GTR-159

Rappole, J. H. (1983). Aves migratorias neárticas en comunidades templadas y tropicales. *El Hornero*, 12(01extra), 208-211. http://hdl.handle.net/20.500.12110/hornero_v012_n01extra_p208

Rodríguez-Yáñez, C. A., Villalón, R., & Navarro, A. G. (1994). Bibliografía de las aves de México (1825-1992). *Publicaciones especiales del Museo de Zoología Núm. 8*. México, D.F.: Facultad de Ciencias, Universidad Nacional Autónoma de México.

Rojas-Soto, O. R., & Oliveras de Ita, A. (2005). Los inventarios avifaunísticos: reflexiones sobre su desarrollo en el Neotrópico. *Ornitologia Neotropical*, 16, 441-445. https://sora.unm.edu/node/119717

Ruvalcaba-Ortega, I., Gonzalez-Rojas, J. I., & Canales-del Castillo, R. (2008). Riparian bird community from the Rio Sabinas, Coahuila, Mexico. *Texas Journal of Science*, 60(4), 243-260.

Sáenz, J. C., Villatoro, F., Ibrahim, M. A., Fajardo, D., & Pérez, M. (2006). Relación entre las comunidades de aves y la vegetación en agropaisajes dominados por la ganadería en Costa Rica, Nicaragua y Colombia. *Agroforestería en las Américas*, 45: 37-48. https://repositorio.catie.ac.cr/handle/11554/7723

Semarnat (Secretaría del Medio Ambiente y Recursos Naturales). (2010). *Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres - Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo*. Diario Oficial de la Federación. 30 de diciembre de 2010, Segunda Sección, México.

Sibley, D. A. (2000). *The Sibley Guide to Birds*. Alfred A. Knopf, Inc., New York, USA 545 p.

Valencia-Herverth, R., Valencia-Herverth, J, Mendoza-Quijano, F., Linate-Ramos, A., & Hernández, L. (2008). Avifauna de dos fragmentos de selva mediana subperennifolia en la Región Huasteca del estado de Hidalgo, México. *TecnoINTELECTO*, 5(1), 13-19. https://www.itvictoria.edu.mx/investigacion/tecnointelecto.html

Villa-Bonilla, B., O. Rojas-Soto, A.G. Colodner-Chamudis & C. Tejeda-Cruz. 2008. Inventarios municipales de avifauna y su aplicación a la conservación: El caso de Zacapoaxtla, Puebla, México. *Ornitología Neotropical*, 19: 531-551. https://sora.unm.edu/node/133459

Villaseñor, J. F., & Santana, E. (2003). El monitoreo de poblaciones: herramientas necesarias para la conservación de las aves en México. Pp. 224-259. *In*: Gómez de Silva, H y A. Oliveras de Ita (Eds.), *Conservación de aves, experiencias en México*. Nacional Fish and Wildlife Foundation, CIPAMEX, CONABIO, México, D.F.

# Chapter 2 General aspects of the life cycle stages of the silkworm *(Bombyx mori)*

# Capítulo 2 Aspectos generales de las etapas del ciclo de vida del gusano de seda *(Bombyx mori)*

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**Abstract**

The objective of this work is to present the main morphological characteristics of the different stages of the life cycle of the silkworm *Bombyx mori*, developed at the Universidad Politécnica de Francisco I. Madero, located in Tepatepec, Hidalgo. Every year, silkworm populations are raised in which Agrotechnology Engineering students are involved to reinforce theoretical-practical knowledge of Entomology. It is concluded that the life cycle of the silkworm is approximately 45 days, passing through egg, larva, pupa and adult.

**Larva, Mulberry, Sericulture, Cocoon, Insect**

**Resumen**

El objetivo de este trabajo es dar a conocer las principales características morfológicas de los diferentes estados del ciclo de vida del gusano de seda *Bombyx mori*, desarrollado en la Universidad Politécnica de Francisco I. Madero, ubicada en Tepatepec, Hidalgo. Cada año se realizan crianza de poblaciones de gusano de seda en donde se involucran alumnos de la Ingeniería en Agrotecnología para reforzar conocimientos teórico-prácticos de Entomología. Se concluye que el ciclo de vida del gusano de seda es de aproximadamente 45 días, pasando por huevo, larva, pupa y adulto.

**Larva, Morera, Sericultura, Capullo, Insecto**

## 2 Introduction

In Mexico, particularly in the state of Hidalgo, due to its economic importance, silkworm cultivation is being promoted to obtain silk thread and to evaluate the nutritional value of the worm (larva) and pupa, in comparison with some edible insects (Rodríguez et al., 2012). The silkworm is the larva of the moth *B. mori* Linnaeus (Lepidoptera: Bombycidae), which produces silk by feeding on the mulberry plant (*Morus alba* L.) of the Moraceae family. It is an insect of the Lepidoptera order, to which belong the so-called "moths" (of nocturnal habits, including the silkworm) and the "butterflies" (of diurnal habits). It is a domesticated insect, which means that it is fully adapted to commercial breeding. In fact, it does not exist in the wild because it has lost the ability to fly and to survive in extreme environmental conditions. It is a species of complete metamorphosis, which means that during its life it goes through the stages of egg, larva or worm, chrysalis or pupa and butterfly. While all stages are very important, particular attention will be paid to the larval and pupal stages. Breeding consists of feeding the worms, which upon entering the chrysalis stage will build a cocoon, with a single silk thread, which is the productive unit (Pescio et al., 2008). It is a domesticated species that has been exploited for more than 5,000 years, the breeds currently reared have been derived from a wild worm B. mandarina Moore, 1872 originating in China, India and Korea. The insect ingests approximately 20-22 g of fresh mulberry or 5-5.5 g of dried mulberry for growth, 40% of the consumption is assimilated and the remaining 60% is eliminated through excrement, and only 25% of the digested food is transformed into raw silk for cocoon formation. The food and its nutritional quality have a great influence on the development of the silkworm, in the larval stage and in cocooning. In order to carry out its morphological development and metabolic functions, the silkworm needs two important nutrients, crude protein and carbohydrates, which are concentrated in high percentages in the young leaves of mulberry trees. The amount of macro- and micronutrients in mulberry leaves influences the content of protein, lipids, carbohydrates, vitamins, minerals and water, and varies according to variety, soil fertility, climate, time of year, age and leaf position (Rodríguez et al., 2016). The purpose of this work is to present the main morphological characteristics of the different stages of the life cycle of the silkworm developed at the Universidad Politécnica Francisco I. Madero.

### 2.1 Methodology to be developed

The academic project financed by the "FOMIX CONACYT 131264" concerning "Mulberry plantations and silkworm populations" has been developed for fourteen years in the Agrotechnology Engineering of the Universidad Politécnica Francisco I. Madero, located in Tepatepec, state of Hidalgo, Mexico. To date, there is a plantation of three mulberry varieties and two silkworm breeds. Every year, rearing of this insect is carried out in which the students of UPFIM and especially those of Agrotechnology carry out practices related to the Entomology and Phytosanitary of the crop, taking data of all the biological stages of the *Bombyx mori* such as egg, larva, pupa and adult, the observations are captured and analysed in the Excel programme.

### 2.2 Results

The mulberry tree is the only plant on which the silkworm feeds, it grows in tropical, subtropical and temperate climates, it can grow in infertile soils, but when grown in rich soils, with regular irrigation, it produces large quantities of high quality leaves, these characteristics are present every year in the UPFIM plantation (figure 1A). Its cultivation has historically been for silkworm rearing, however, mulberry has a variety of uses: as livestock feed, fruit production, medicinal recipes, garden construction, paper products, timber and firewood production. Mora 2010, carried out experiments on the diet of rabbits using mulberry leaves as fodder, obtaining good results.

Silkworm eggs are round, 1 to 1.3 mm long and 0.9 to 1.2 mm wide, they can be oval, flattened or ellipsoidal, at the time of oviposition they have a yellowish-white colouring that will vary in the following hours, until, finally, it turns grey (figure 2). Pescio et al., (2006), report that the egg stage comprises the resting period of their active life and from this several types of races or biological groups of the silkworm can be classified. The races are classified according to the type of diapause: univoltine and polyvoltine. Univoltine silkworms have only one cycle per year; bivoltine silkworms have two cycles per year, while polyvoltine silkworms have a very small diapause and can develop several generations per year. The duration of this state depends on the breed and type of diapause or dormancy. Diapause is the suspension of development. Eggs with diapause are those with two stages of embryonic development. The first stage takes place during the 48 hours, during which embryo development stops, and the second stage, hibernation, of variable duration, and which needs specific environmental conditions to become active.

Álvarez, 1993, reports that they are elliptical in shape with a smooth chorion, and measure 1 mm wide by 1.3 mm long. Freshly laid, they are pale yellow in colour. As the embryo develops, the colour of the eggs varies. At 40 hours of age, the eggs become pinkish in colour, and at 72 hours, their colouring is ochre. He also mentions that the larvae, before hatching, open a hole in the chorion and are black when hatched. The body is covered with long, light brown setae, the setae emerge from warts located on the anterior part of the three thoracic segments and the eight abdominal segments; a caudal horn is observed on the eighth abdominal segment, and as they develop, they change colour until they become white. We report that the worm is the most active, because a series of processes and changes occur, such as feeding, metabolism, skin changes, silk secretion and cocoon development. The larvae (figure 2C) have a rigid cuticle that limits the size of the insect, which is why it can only grow by shedding its old exoskeleton and making a larger one, a process called molting. The larva loses its appetite, raises its head, its body becomes tense and creamy in colour, and it becomes restless as it approaches moulting.

The pupal stage is a dormant stage, when the insect is unable to eat and appears completely still. It is a transient phase during which changes in the shape of the insect are defined. Pupation is important because hysterolysis occurs in some larval organs, such as the sericine gland, abdominal legs and ocelli (figure 2D). Similar observations are reported by Alvarez 1993, the pupae are of the obcta type; newly formed pupae are light green in colour and after 24 hours they turn brown. The average duration of this stage ranges from 15 to 40 days. The pupal stage is generally called the resting, dormant stage and is the stage when the insect is unable to eat and appears completely still. The pupal stage is a transient phase during which changes in the shape of the insect are defined.

The pupal stage is important because hystolysis occurs in some larval organs, such as the sericeous gland, abdominal legs, ocelli, etc. Other organs also change their shape and specific functions in the adult. The duration of this stage is 12 to 15 days, and it is relatively fixed and finished when the butterfly emerges from the cocoon (Pescio *et al*., 2008).

The silk cocoon formed by two proteins is a protective structure that the worms build with a single silk filament, prior to their transformation into a butterfly (figure 2.1). Rodriguez et al., 2013, mention that on average it weighs 1.8 g without chrysalis or pupa (figure 2E). The filament is made up of slime secreted from the serigal glands. Silk filaments are generally 20-30% sericin and 70-80% fibroin. The components of fibroin and sericin are: C, H, O, N and S.

**Figure 1** Biological stages of the silkworm Bombyx mori at the Universidad Politécnica Francisco I. Madero, Tepatepec, Hidalgo. Mulberry crop (A), eggs and hatching larvae (B), last instar larva (C), pupae (D), cocoons (E) and adult or moth (F)

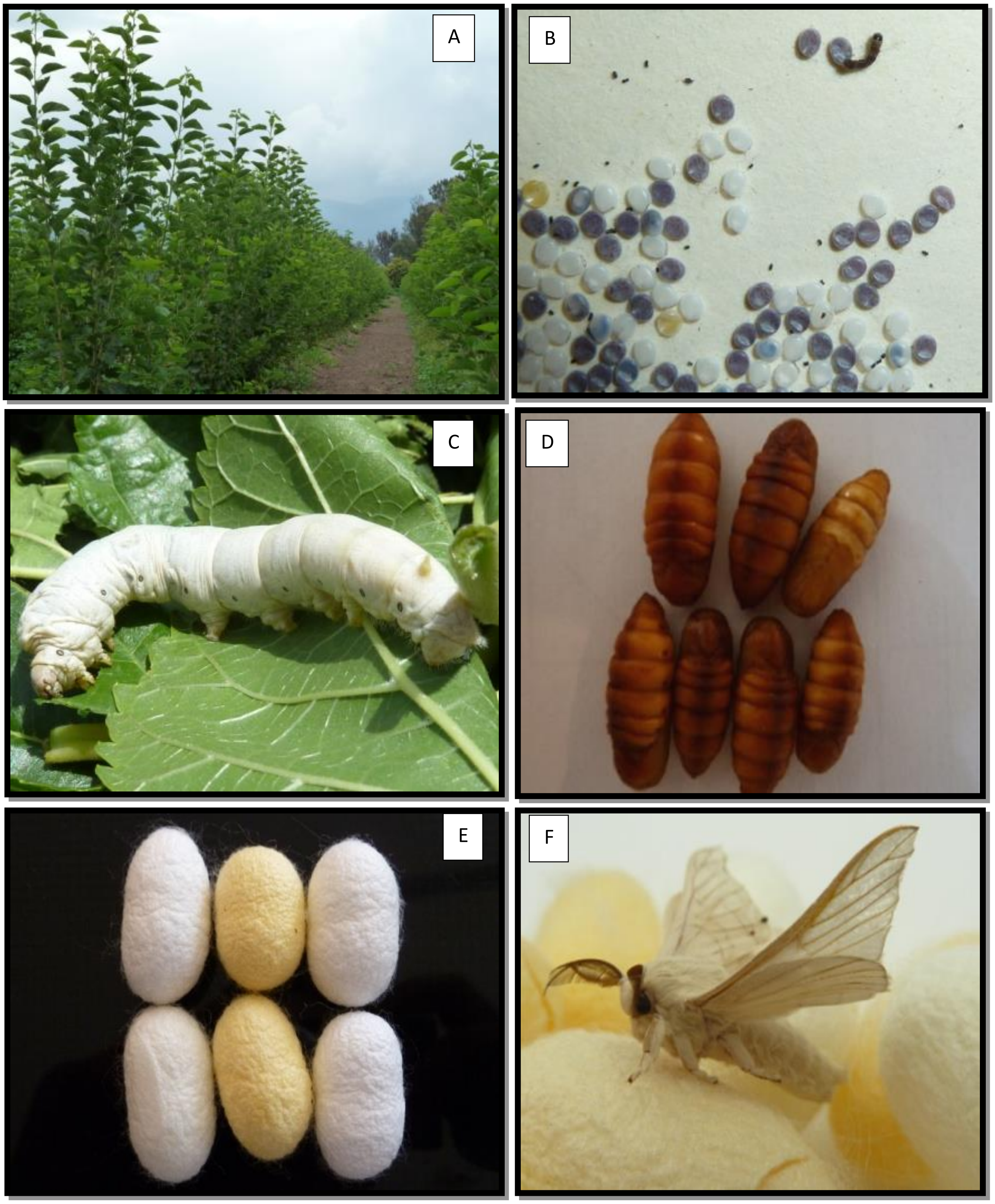
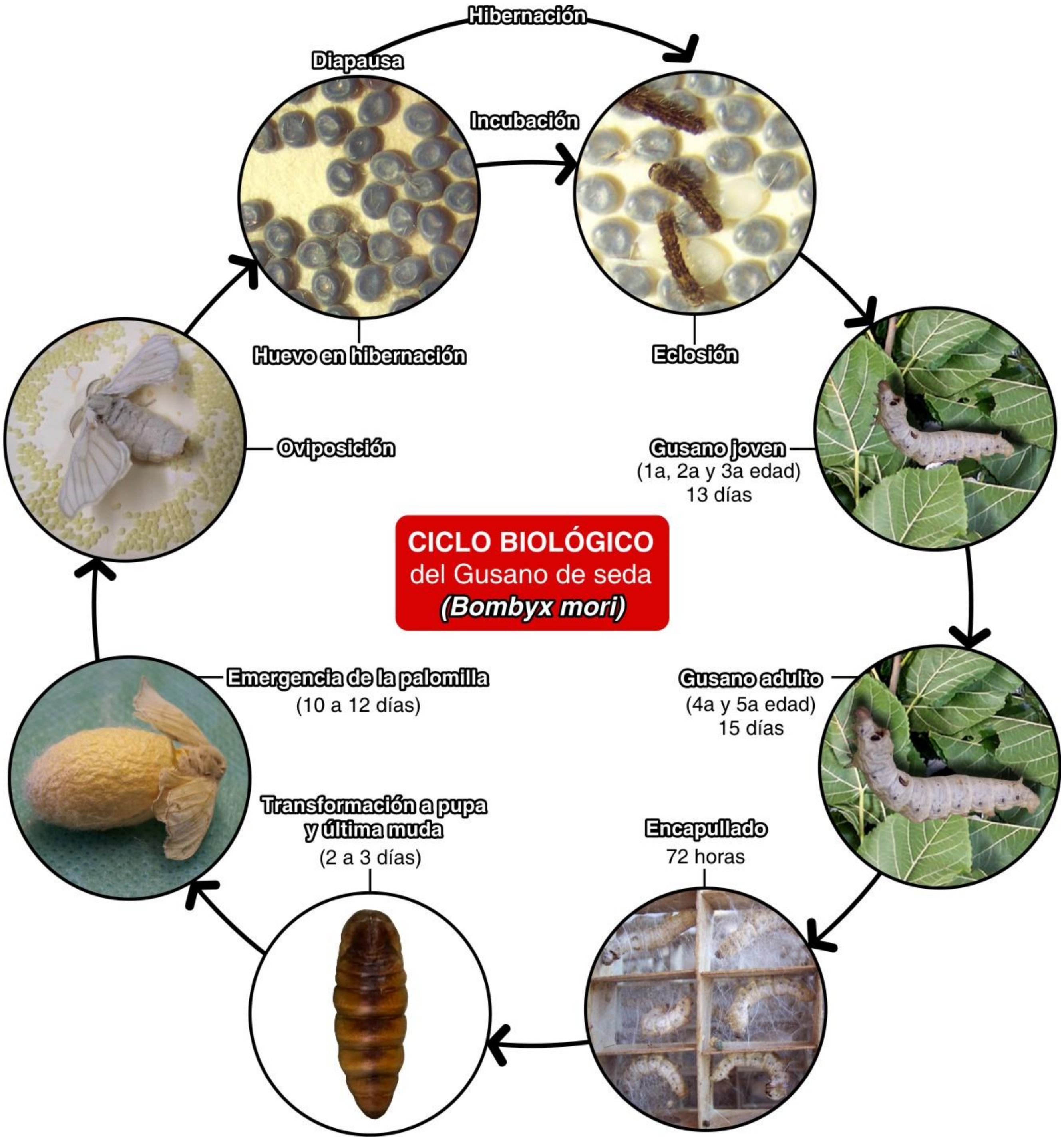


**Figure 2.1** Life cycle stages of the silkworm, personal communication with the Centro Nacional de Sericultura de San Luis Potosí




The moth consists of three parts: head, thorax and abdomen (figure 2.1). The body is covered with white scales and there are three pairs of legs and two pairs of wings on the thorax. Their function is exclusively reproductive, they cannot fly or feed. The head of the adult has two feathery antennae which are used to perceive the smell of pheromones, especially those of the larger male (figure 2F). Similar information is reported by Salice *et al*., (2001), who state that the moth consists of three parts: head, thorax and abdomen. The body is covered with white scales and there are three pairs of legs and two pairs of wings on the thorax. Their sole function is reproduction, they cannot fly or feed. The head of the adult has two feathery antennae, which are used to perceive the smell of pheromones, especially in the larger male. Sex can be easily distinguished in this state because the female has a larger body than the male due to the large number of eggs contained in the abdomen.

## 2.3 Acknowledgement

Special thanks are due to the Agrotechnology Engineering Department of the Universidad Politécnica Francisco I. Madero, for the facilities provided for the completion of this project and to the mixed funds of CONACYT for their financing.

## 2.4 Conclusion

Finally, it is concluded from this work that the life cycle of the silkworm is approximately 45 days, passing through egg, larva, pupa and adult, and that up to four broods can be carried out per year, given suitable climatic and phytosanitary conditions for the insects and the mulberry crop.

## 2.5 References

Alonso Álvarez, R.1 993. Biología del gusano de seda, *Bombyx mor* L. (Lepidoptera: Bombycidae). Revista Colombiana de Entomología. Vol. 19 No. 4, p. 119-122.
https://doi.org/10.25100/socolen.v19i4.10067

Mora-Valverde, David. 2010. Usos de la morera (*Morus alba*) en la alimentación del conejo. El rol de la fibra y la proteína en el tracto digestivo. Agronomía Mesoamericana, vol. 21, núm. 2, pp. 357-366.
https://www.scielo.sa.cr/scielo.php?pid=S1659-13212010000200017&script=sci_abstract&tlng=es

Pescio F.; Zunini H.; Claudio Pedro Basso C. P.; De Sesar D. M.; Frank R. G.; Pelicano A. E. y Vieites C. M. 2008. Sericicultura Manual para la producción. Instituto Nacional de Tecnología Industrial. Buenos Aires, Argentina. 187 p.
https://huertasescolares.files.wordpress.com/2013/06/manual-seda-1.pdf

Rodríguez, O. A.; Vargas, M. J.; Ventura, M. A.; Martínez, M. A.; Rodríguez, M. J.; Ehsan, M.; Lara, V. F. M. 2012. Manual de Sericultura en Hidalgo, principios Básicos. Primera edición. Universidad Politécnica de Francisco I. Madero. México. 102 p.
https://upfim.edu.mx/wp-content/investigacion/libros/Libro%202012%20Manual%20de%20Sericultura%20en%20Hidalgo.pdf?_t=1686948044

Rodríguez-Ortega, A.; Martínez-Menchaca, A.; Ventura-Maza, A.; Vargas-Monter, J.; Muhammad, E.; y Lara Viveros, F. M. 2013. Evaluación de variedades de morera en la alimentación del gusano de seda (*Bombyx mori*) en Hidalgo, México. Revista Mexicana de Ciencias Agrícolas Vol.4 Núm.5, p. 701-712.
https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-09342013000500004

Rodríguez-Ortega, A.; Pino-Moreno, J. M.; Ángeles-Campos, S. C.; García-Pérez, Á.; Barrón-Yánez, R. M.; Callejas-Hernández, J. 2016. Valor nutritivo de larvas y pupas de gusano de seda (*Bombyx mori*) (Lepidoptera: Bombycidae). Revista Colombiana de Entomología 42 (1): 69- 74.
https://doi.org/10.25100/socolen.v42i1.6672

Salice, G., Soria, S. y Avendaño, F. 2001. Guía Práctica de Sericultura. ROMA. pp. 87-128.

# Chapter 3 Agroecological management of coffee for sustainable production: Ayotzin offee case – union of producers, Cuetzalan del Progreso, Puebla

# Capítulo 3 Manejo agroecológico del café para la producción sustentable: caso ofertorio Ayotzin - unión de productores, Cuetzalan del Progreso, Puebla

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I. Martínez, Y. Osorio, F. Martínez and K. Aguilar. (VV. AA.) Sustainability in agricultural production and natural resource management T-I Biotechnology and Agricultural Sciences. Handbooks-©ECORFAN-México, Hidalgo, 2023.

**Abstract**

In Mexico, coffee production is grown on small extensions of land, mostly by indigenous producers, with an average of 1.4 hectares (Ha) per producer. The production zones are characterized by latitude, altitude and by the conditions of marginalization and poverty of the producers. In Café Ayotzin we start by working on the organization of the producers to carry out a field sampling to carry out an agroecological and sustainable management that benefits the yields in coffee production, having as main objective the recovery of coffee production in quantity (ton $ha^{-1}$) and quality (cup value) to generate confidence in the producer, avoiding intermediation, practicing fair trade and sustainability. The field work is carried out with technical advice on seed selection, germination and nurseries, management of good cultural practices such as pruning, fertilization with bocashi or biol, application of insecticides such as Bordeaux mixture, and the transplanting of new plants in the field. Finally, advice is given on the management of the wet and dry processing to obtain the final product, a pure roasted and ground coffee. With the good practices in the field and the commitment to manage the plants in an agroecological manner, we went from obtaining less than 1.5-ton $ha^{-1}$ in the region to producing 2.1 ton $ha^{-1}$ per producer.

**Coffee, Sustainability, Production, Agroecological, Management, Poverty, Management, Poverty**

**Resumen**

En México, la producción de café se cultiva en pequeñas extensiones de terreno la mayoría por productores indígenas teniendo un promedio de 1.4 hectáreas (Ha) por productor. Las zonas de producción se caracterizan por la latitud, altitud y por las condiciones de marginación y pobreza de los productores. En Café Ayotzin se empieza trabajando por la organización de los productores para realizar un muestreo de terreno para llevar a cabo un manejo agroecológico y sustentable que beneficie los rendimientos en la producción de café, teniendo como objetivo principal la recuperación de la producción de café en cantidad (ton $ha^{-1}$) y calidad (valor en taza) para generar confianza en el productor evitando el intermediarismo, practicando el comercio justo y la sustentabilidad. El trabajo en campo se realiza con el asesoramiento técnico en la selección de semillas, realización de germinadores y viveros, manejo de buenas prácticas culturales como: poda, fertilización con bocashi o biol, aplicación de insecticidas como caldo bordelés, y el trasplante en campo de las nuevas platas. Finalmente se asesora en el manejo del beneficio húmedo y seco para obtener el producto final, un café puro tostado y molido. Con las buenas prácticas en campo y el compromiso en el manejo de las plantas de una forma agroecológica se pasó de obtener menos de 1.5 ton $ha^{-1}$ en la región a producir 2.1 ton $ha^{-1}$ por productor.

**Café, Sustentabilidad, Producción, Agroecológico, Manejo, Pobreza**

## 3 Introduction

In Mexico, coffee production is cultivated on small plots of land by mostly indigenous producers. Normally due to the altitude and latitude that favours production, they are characterised by areas where producers live in conditions of marginalisation and poverty. Poor marketing and management of coffee production has resulted in low prices, which leads to a decrease in income, unemployment, migration and total or partial abandonment of the farms, which generates a deepening of poverty in the families that depend on this activity.

At the national level, the majority of producers are smallholders, with an average of 1.4 hectares (ha) per producer, i.e., of the 684,763-ha planted with coffee, there are only 486,314 producers, 70% of which are indigenous (Aragón. 2006).

For this reason, the coffee sector in Mexico has participated in the history and economic, political, social and cultural development of the country, where production is connected to the international or national market through regional hoarders, brokers and transnational companies, who demand the beans from regional processing and marketing companies (Martínez, 1996).

Puebla is the third largest coffee-producing state in the country; 75% is destined for export, mainly washed raw coffee and high altitude coffee. According to the Sistema Producto Café (SIAP, 2015), the municipality of Cuetzalan has a harvested area of 4800 hectares, a production of 8833 tonnes and a yield of 1.84 tonnes per hectare (ton ha-1). The municipality has 5786 coffee producers (Ramírez et al., 2006).

Currently, Cuetzalan del Progreso produces 6,582 tons (Blog gobmx, 2023) which indicates a low coffee production, identifying as main problems: low productivity (-1.5-ton $ha^{-1}$) preferring to produce other agricultural products, low technology in the field, poor management of agricultural practices, inappropriate coffee varieties, technical and commercial training, adverse climatic events and phytosanitary problems (borer, rust, etc.) among others. These problems cause the majority of producers to be displaced in search of better income for their families, choosing to move to cities for better living conditions and as a consequence abandoning the coffee field.

The objective of this work, the creation of the Café Ayotzin brand in conjunction with the producers' organisation (Unión de Productores de Café) is the recovery of coffee production in terms of quantity (ton $ha^{-1}$) and quality (cup value) in order to generate confidence in the producer, avoiding middlemen, practising fair trade and sustainability.

**3.1 Methodology**

Café Ayotzin was born on December 18, 2019 in the community of Ayotzinapan, Cuetzalan del Progreso, Puebla, consolidated by a group of producers in the region with the support of technicians for advice, in order to return to ensure confidence in their production, and seek to recover the yield of coffee within the communities of the municipality, which in previous years supported the economy of indigenous families making this production sustainable, environmentally friendly and with timely use of natural resources.

The purpose of CAFÉ AYOTZIN "help to produce" is to support the producer in a complete technical advice from the selection of the best seeds for the realization of a germinator to later make a nursery to carry out the cultural practices within the farm, and its harvest; in addition to this, the added value and brand to coffee is implemented, taking it to the packaging: This is done in an artisanal way by the practice of the inhabitants who have been managing it for more than 40 years, generating a plus in the profits of the producers and avoiding the middleman.

Sixty percent of the producers have secondary schooling and 40% primary schooling, their mother tongue is Nahuatl, with Spanish as a second language, 75% are between 45 and 55 years old and 25% between 60 and 75 years old, with a total group of 37 producers located in the communities of Ayotzinapan, Xaltipan and Reyeshogpan, with an average of 1.25 hectares of land producing arabica coffee of the typica varieties: caturra and geisha; and hybrid varieties such as: mundo novo, oro azteca and costa rica.

Café Ayotzin begins its work in the field with the producers in the technical advice in their plots carrying out:

1. Organization of groups.
2. Production problems.
3. Identification of the variety.
4. Selection of the best seeds.
5. Sowing in the field.
6. Agricultural practices.
7. Harvesting.

8. Wet and dry processing.

9. Roasting.

10. Milling of Ayotzin coffee.

The organization of the groups begins with the extension of the work programme, offering technical follow-up in the field, guaranteeing added value to the final product. The producers who join the work team begin with the evaluation of the farm, taking soil samples to obtain the hydrogen ion potential (pH), where an average of 5.3 was obtained, which is an acceptable range for coffee production, as indicated by Sadeghian, 2016. 3 which is an acceptable range for coffee production as indicated by Sadeghian, 2016 where the optimum point is 5 to 5.5 pH, on the other hand the soil texture was evaluated obtaining 90% of soil loam-sandy clay and 10% with sandy loam texture and finally the thickness of the mulch had an average of 3.5 centimeters (cm) being 60% and 40% of 4.7 cm. Subsequently, the problems began to be corrected, starting with the mulch to reach the optimum, which is 5 cm thick, and in some farms the pH levels were corrected.

Once the variety had been identified, the selection of the best fruit from each plot and from each producer began, in order to be able to make the germinators and then organise the people to equip the nursery, which is why the geisha fruit was chosen and selected for its cup quality; oro azteca and mundo novo, for their resistance to pests and diseases.

The germination of the germinators is done by training the personnel for the maintenance of the same, obtaining a range of germination of 60 to 70 days, and from 80-90 days the chapolas are obtained, which with two fully extended cotyledonous leaves are transplanted to the nursery with fertile soil, obtaining from the preparation of organic fertilisers such as bocashi.

After 7 to 8 months and reaching a height of 15 to 20 cm, the coffee plants can be transplanted in the ground with prior advice, where a distance of 1.70 meters (m) long x 1.40 meters (m) wide for geisha, 2 m x 1.70 m for mundo novo and 1.90 m x 1.60 m for oro azteca, all plants were distributed equally according to their needs of varieties in each producer.

**Figure 3** Sowing coffee in germinators with single rows or broadcast

Working in a sustainable way, we choose to maintain the plots by pruning, fertilising with organic fertilisers or biols and fighting pests using sulphocalcic broths and cleaning the plots using the "chapote" (cleaning with a machete) to avoid the use of herbicides.

**Figure 3.1** Soil preparation and transplanting of the seedling to the nursery

**Figure 3.2** Preparation of Bocashi

During harvesting, the fruit is strategically selected in three stages: intense dark-red, light-red and yellow-red, which will influence the cup quality, specifically the body and acidity.

After harvesting, the ripe fruit is selected, avoiding dried or half-seeded fruit for subsequent pulping. Washing can be carried out in three ways depending on market demand: natural washing, where after pulping it is left to ferment for 24 to 48 hours for subsequent washing, natural or dry process where the ripe fruit is left to dry in the open air without the need for pulping so that it absorbs the sugars better and the last process is honney or enmielado where after pulping it is left to dry with the mucilage of the coffee.

After drying the parchment coffee, the different seeds are classified into different sizes for subsequent cleaning and thus obtaining the gold or green coffee, which is then classified again for roasting and grinding, and finally for packaging.

All the residues obtained in each process are handled for their subsequent reincorporation on the farm, either to be used as fertiliser or to be reused to increase the mulch and thus avoid all types of erosion or landslides due to the slopes and rains in the area.

## 3.2 Results

**Figure 3.3** Obtaining coffee seedlings planted on the farms of each producer

The organisation of the people and the follow-up in the field to improve their production in terms of quality and quantity, a yield of 2.1 ton $ha^{-1}$ is obtained, thanks to a previous diagnosis of the land to carry out an agro-ecological and sustainable management.

The timely implementation and advice at each stage of production led to obtaining a quality coffee with higher yields, while at the same time the idea of working the farms without overexploiting them, generating a friendly environment in the biomass and coffee ecosystem is taken up again.

This is how the final product, ground and roasted coffee in its different presentations, is inserted into the national and international market, working in fair trade to support the economy of the families, boosting their production.

## 3.3 Conclusions

The agricultural crisis of coffee in Cuetzalan has caused people to move to other activities that generate support for their families, for this reason the project has returned to embrace and generate confidence in the producers by the way of working and the results obtained, that is why Ayotzin Coffee becomes a sustainable, efficient, productive and inclusive project becoming an organic production system.

## 3.4 References

Aragón, C. (2006). Cafeticultura, inequidad y pobreza. En: Productores indígenas de café de la Sierra Nororiente de Puebla. Coordinadores: Ramírez, B., Juárez, J. P. y Cesín, A., Colegio de Postgraduados y FOMIX.

Blog Gobierno de México. 2023. Representación agricultura Puebla, México. https://www.gob.mx/agricultura/puebla/articulos/puebla-alcanza-el-3er-lugar-a-nivel-nacional-del-valor-de-produccion-de-cafe?idiom=es

Martínez, Aurora Cristina. 1996. El proceso cafetalero mexicano. Universidad Nacional Autónoma de México, Instituto de Investigaciones Económicas, Consejo Latinoamericano de Ciencias Sociales, Universidad Central de Venezuela, México, Distrito Federal.

Ramírez, Benito, y Adrián González. 2006. La migración como respuesta de los campesinos ante la crisis del café: estudio en tres municipios del estado de Puebla. Universidad Autónoma Indígena de México. Mochicahui, El Fuerte, Sinaloa.

Sadeghian, K. Siavosh (2016). Revista Avances Técnicos 466. CENICAFE. Manizales, Caldas, Colombia. https://biblioteca.cenicafe.org/bitstream/10778/704/1/avt0466.pdf

SIAP. 2015. Sistema Producto café. Producción Agrícola. Ciclos Perennes 2010. México. https://www.gob.mx/siap/acciones-y-programas/produccion-agricola-33119.

# Chapter 4 Agroecological management of flora for pollinator reserves in Metztitlán, Hidalgo

# Capítulo 4 Manejo agroecológico de la flora para reserva de polinizadores en Metztitlán, Hidalgo

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I. Martínez, Y. Osorio, F. Martínez and K. Aguilar. (VV. AA.) Sustainability in agricultural production and natural resource management T-I Biotechnology and Agricultural Sciences. Handbooks-©ECORFAN-México, Hidalgo, 2023.

**Abstract**

La Vega de Metztitlán is part of the Barranca de Metztitlán Federal Biosphere Reserve in the state of Hidalgo. There, the most important economic activity is agriculture, since 73% of the population of the municipalities that make up the area grow beans, corn, green beans, zucchini, tomato, chili, sorghum and walnut. The indiscriminate use of agrochemicals due to the implementation of three production cycles per year has caused a considerable reduction in beneficial fauna and a decrease in yields due to low or no natural pollination. With the objective of preserving pollinating insects in the Metztitlán ravine, an agroecological plot was established at the Universidad Politécnica Francisco I. Madero, Metztitlán Academic Unit, under strictly ecological management with the rational use of natural resources, as well as a control of pests and diseases based on plant extracts. For this purpose, the cultivation of sunflower (*Helianthus annus*) was implemented as part of the strategy to attract pollinating insects and thus determine their incidence. The results showed the presence of Hymenoptera in 90%, Lepidoptera, Coleoptera and Hemiptera 3% respectively in each order. For the prevention and control of pests, chili extract plus garlic was used, which had 95% efficiency. The agroecological management of crops is a sustainable alternative for the preservation, attraction and increase in the incidence of pollinating insects, considerably increasing final yields.

**Agroecología, Insectos, Repelentes, Orgánico**

**Resumen**

La Vega de Metztitlán forma parte de la Reserva federal de la Biosfera Barranca de Metztitlán en el estado de Hidalgo. En esta, la actividad económica de mayor importancia es la agricultura, ya que el 73% de la población de los municipios que conforman el área, se siembran frijol, maíz, ejote, calabacita, jitomate, chile, sorgo y nogal. El uso indiscriminado de agroquímicos a causa de la implementación de tres ciclos de producción al año ha ocasionado una reducción considerable de la fauna benéfica y disminución en los rendimientos por causa de la baja o nula polinización natural. Con el objetivo de preservar los insectos polinizadores en la barranca de Metztitlán, se estableció una parcela agroecológica en la Universidad Politécnica de Francisco I. Madero, Unidad Académica Metztitlán, bajo un manejo estrictamente ecológico con el uso racional de los recursos naturales, así como un control de plagas y enfermedades a base de extractos vegetales. Para ello se implementó el cultivo de girasol (*Helianthus annus*) como parte de la estrategia de atracción de insectos polinizadores y así determinar la incidencia de estos. Los resultados mostraron la presencia de himenópteros en un 90%, lepidóptera, coleóptera y hemíptera de 3% respectivamente a cada orden. Para la prevención y control de plagas se utilizó el extracto de chile más ajo él cual tuvo un 95% de eficiencia. El manejo agroecológico de los cultivos es una alternativa sustentable para la preservación, atracción y aumento en la incidencia de insectos polinizadores, aumentando considerablemente los rendimientos finales.

**Agroecology, Insects, Insect, Repellents, Organic**

## 4 Introduction

The agricultural area known as "La Vega de Metztitlán" is part of the federal Biosphere Reserve Barranca de Metztitlán in the state of Hidalgo. The most important economic activity in this area is agriculture, as 73% of the population of the municipalities that make up the area grows beans, maize, green beans, squash, tomatoes, chilli, sorghum and walnuts. The indiscriminate use of agrochemicals due to the implementation of three production cycles per year has caused a considerable reduction in beneficial fauna and reduced yields due to low or no natural pollination. In order to preserve pollinating insects in the Metztitlán ravine, an agro-ecological plot was established at the Polytechnic University of Francisco I. Madero, Metztitlán Academic Unit, under strictly ecological management with the rational use of natural resources, as well as pest control based on plant extracts. As part of the strategy to attract pollinating insects, the establishment of a sunflower crop (Helianthus annus) was also implemented in order to determine the incidence of these insects. In the worldwide erosion of biodiversity, dramatic evidence emerges of losses in the insects that carry out pollination activities, with bees (Apis mellifera) being the most relevant, which represents a major risk for agricultural production and food security.

About 60 to 90 % of plant species require a pollinator for their reproduction Kremen et al., (2007), the ecological, economic and conservation importance of the role they play in wild and cultivated flora Buchmann and Ascher, (2005). This work aims to determine the importance of agroecological use in crops and the implementation of insect-attracting plants to aid pollination.

### 4.1 Materials and methods

The present project was carried out at the Universidad Politécnica de Francisco I. Madero, Unidad Académica de Metztitlán, located at Domicilio conocido avenida Tepeyacapa, s/n. (Fig. 4).

**Figure 4** Location of the study area

For the establishment of the crop, the soil was prepared using a 12-disc harrow to condition the soil, in order to incorporate residues from the previous sowing, increase porosity, expose the harmful fauna present and decompact the soil. The tillage depth was 30 cm, according to the soil profile and the root capacity of the crop. The distance between furrows was 0.80 m. with a length of 30 m. in a total of 25 furrows. The established seed variety was Vicents Choice. Its main characteristics are short cycle, 60 days to flowering, medium size and resistance to low temperatures. Sowing was carried out on 20 May 2023, in soil with moisture at field capacity and manually, distributing the seeds at a distance of 15 cm between plants at a depth of 5 cm. For nutrition, the formula (20-30-10) of NPK plus micronutrients was applied to correct deficiencies, the dose used was 200 $g^{-1}$ in 15 l-1 of water. The applications were made at 15-day intervals over a period of two months. Irrigation was applied at three-day intervals, based on the requirements of each phenological cycle, taking into account the potential evapotranspiration factors.

The application system was by means of localized irrigation (cintilla) using a supply system made up of a pipe, a polyduct with a diameter of 2 inches and a 1.5 HP pump with 45 PSI with a flow rate of 20 l-1 per second. The duration of each irrigation was 3.5 l/hr with uniformity of the wetting bulb of the root system. The main pests that were present were: aphid (Aphididae), whitefly (*Bemisia tabaci*), leafhopper (*Brachystola magna*), diabrotica (Diabrotica L.), chinch bug (*Cimex lectularius*). Natural extracts based on garlic, hot chilli, cinnamon and neem were used to control these pests, at a dose of 200 ml-1 in 15 l-1 of water. The applications were made for preventive control. To determine the incidence of pollinating insects, daily counts were carried out in 5 sampling points per m2 during the flowering stage and later identified for classification.

### 4.2 Results and discussions

**Table 4** Incidence of pollinating insects per $m^2$

| Phenological stage | Hymenoptera | Lepidoptera | Coleoptera | Hemiptera | % |
|---|---|---|---|---|---|
| Flowering | 90% | 3% | 3% | 3% | 100% |

The results obtained according to the incidence of pollinating insects per square metre in the phenological stage of flowering are shown, where 4 different percentages were obtained according to the orders presented. Bees belong to the order of insects corresponding to Hymenoptera, and constitute the superfamily Apoidea, which includes seven families, about 425 genera and more than 20 000 species, Michener; (2000). In this case they occupied the highest percentage of occurrence despite the largely disturbed area. The pollination activities that bees provide to the ecosystem they inhabit are extremely important, as they help to preserve the integrity of the ecosystem Gallai et al. Despite modern agricultural management and practices, pollinating insect populations are declining at an alarming rate. Studies have shown that with entomophilous pollination, fruit size and weight increase considerably compared to fruit produced without the intervention of pollinators Guzman et al. Bees are known to be used for pollination of crops and native flora Roubik *et al*., (1991).

Table 4.1Plant density /ha$^{-1}$

| M linear | M linear/ ha$^{-1}$ | Plants/linear m | Plants /ha$^{-1}$ |
|---|---|---|---|
| 750 | 12500 | 7 | 5250 |

The results obtained from the density of plants /ha$^{-1}$ , with the linear metres established in the sowing area, are shown in order to determine the number of plants for the incidence and refuge of pollinating insects, as well as to associate the yield of neighbouring crops which benefit from the fertilisation provided. According to the density and taking into account the constancy of the bee with genotypes that increase pollen availability or devices that promote pollen transfer at the entrance of the hives Hatjina et al. (1999), could increase crop yields. The arrangement of the plants per m2 is a function of genotypes adapted for high densities, so it is suggested that growers define the variety with ideal botanical aspects and implement production improvement techniques with studies related to the cognitive abilities of the pollinator of each system. Aguirrezábal et al. (1996) argue that the available space offered by the receptacle tissue for new flowers to differentiate is a determining factor for the total number of flowers that can develop and therefore the total number of fruits.

**Table 4.2** Extracts used for pest control

| Pests | IA | Dose | % from efficiency |
|---|---|---|---|
| Aphid | Garlic extract *(Allium sativum)* | 200 ml$^{-1}$ /15 l$^{-1}$ of water | 85% |
| Whitefly | Chilli extract*(Capsicum annuum)* | 200 ml$^{-1}$/ 15 l$^{-1}$ of water | 95% |
| Bedbug | Cinnamon extract *(Cinnanomomum verum)* | 200 ml$^{-1}$ /15 l$^{-1}$ of water | 75% |
| Diabrotica | Neem extract(*Azadirachta indica*) | 200 ml$^{-1}$ /15 l$^{-1}$ of water | 50% |
| Leafhopper | Chilli + garlic extract*(Capsicum annuum + Allium sativum)* | 200 ml$^{-1}$ /15 l$^{-1}$ of water | 95% |

With the results of the applications made for the control of the different pests that occurred during the crop cycle, as well as the doses and the percentage of efficiency obtained. It is shown that the chilli extract plus garlic extract obtained 95% control for leafhoppers, the chilli extract obtained 95% for whitefly, the garlic extract 85% for aphids, the cinnamon extract had 75% efficiency in controlling the chinch bug and the neem extract 50% for diabrotica. The application of synthetic insecticides has so far been the most widely used tool to combat the insect. Hilje (1993) mentions that B. tabaci has the facility to develop resistance to insecticides, mainly due to its short life cycle and facultative parthenogenesis. Since 1987, worldwide, this species has developed resistance to 16 insecticides of different chemical origin in cotton plantations. Espinel et al. (2008). Because B. tabaci has the characteristics of resistance, it had to be treated preventively with short application intervals. Insecticides of botanical origin are classified as biochemicals and are an important group of natural crop protectants, which act slowly, incorporate mixtures of biologically active compounds and do not develop resistance in pests. In their basic form, botanical pesticides can be crude preparations of plants, such as powders of flowers, roots, seeds, leaves, stems and essential oils. Formulations are commonly concentrated or liquid extracts, Pavela (2016).

## 4.3 Conclusions

Agroecology is an alternative to minimise pollution in the use of synthetic pest control products and increase the incidence of pollinating insects.

The use of organic repellents used for pest prevention in the chili pepper extract for whitefly and leafhopper had a 95% efficiency.

The incidence of pollinating insects per $m^2$ occurred in the flowering phenological stage, with the order Hymenoptera being the most abundant with 90%, while the orders Lepidoptera, Coleoptera and Hemiptera were 3%.

**4.4 References**

Aguirrezábal, L.A., Orioli, G.A., Hernández, L.F., Pereyra, V.R., y Miravé, J.P. 1996. Girasol: Aspectos fisiológicos que determinan el rendimiento. INTA Unidad Integrada Balcarce. http://www.asagir.org.ar/descargar-archivo-109/archivos-c16844dbaac3a8fde2b71fadbc48 f7dd.

Buchmann, S. y J. S. Ascher. 2005. La difícil situación de las abejas polinizadoras. México. *Apitec* 51: 21-26.

Espinel, C; Lozano, MD; Villamizar, R; Grijalba, B; Cotes, AM. 2008. Estrategia MIP para el control de Bemisia tabaci (Hemiptera: Aleyrodidae) en melón y tomate. Revista Colombiana de Entomología 34(2):1-6.

Guzmán M. A., M. Rincón y R. Vandame. 2004. Manejo y conservación de abejas nativas sin aguijón (Apidae: Meliponini). 36 pp.

Hatjina, F., J. B. Free y R. J. Paxton (1999). "Hive-entrance pollen transfer devices to increase the cross-pollination of honeybee. II. Examination of three materials and pollen viability." Journal of Apicultural Research 38(1-2): 3-9.

Hilje, L. 1993. Las moscas blancas en Costa Rica. In Las moscas blancas (Homóptera: Aleyrodidae) en América Central y el Caribe. (Serie Técnica; Informe Técnico, 205)

Kremen, C., N. M. Williams y R. W. Thorp. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land- use. change. *Ecol Letters*10: 299-314.

Michener, C. 2000. The Bees of the World. The John Hopkins University Press. Baltimore, Estados Unidos. 913 pp.

Gallai, N., J. M. Salles, J. Settele y B. E. Vaissière. 2009 (dato no publ.). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline,Ecological Economics.

Pavela, R. 2016. History, presence and perspective of using plant extracts as commercial botanical insecticides and farm products for protection against insects - a review. Plant Protect. Sci. 52(4):229-241. https://doi.org/10.17221/31/2016-PPS.

Roubik, D. W., R. Villanueva, E. F. Cabrera y W. Colli. 1991. Abejas Nativas de la Reserva de la Biosfera de Sian Ka'an. pp. 317-320. En: Navarro, L. D. y J. G. Robinson. Diversidad Biológica de la Reserva de la Biosfera de Sian Ka'an, Quintana Roo, México. Ciqro, Chetumal, Quintana Roo, México.

Rodríguez Ortega A., Gómez Mercado R., Barrón Yánez R., Martínez Mejía B., Escamilla Flores G Evaluación de híbridos de girasol (Helianthus annus L.) en régimen de temporal en el Valle del Mezquital, Hidalgo. Edición 2017. Pg. 15-35.

# Chapter 5 Evaluation of the monitoring of the asian citrus psyllid, *Diaphorina citri* Kuwayama in the orange zone of Querétaro

# Capítulo 5 Evaluación del monitoreo del psilido asiático de los cítricos, *Diaphorina citri* Kuwayama en la zona naranjera de Querétaro

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I. Martínez, Y. Osorio, F. Martínez and K. Aguilar. (VV. AA.) Sustainability in agricultural production and natural resource management T-I Biotechnology and Agricultural Sciences. Handbooks-©ECORFAN-México, Hidalgo, 2023.

**Abstract**

The Asian citrus psyllid *Diaphorina citri* Kuwayama, in complex with the phytopathogenic bacteria *Candidatus liberibacter asiaticus*, causes Huanglongbing disease that affects citrus production in Mexico, placed among the main producers of lemon, orange and mandarin. Thus, citrus farming is in serious trouble. Associate the environmental variables and site conditions with the incidence of psyllid. 20 yellow traps were placed in five orchards of orange. The number of adults and nymphs was recorded in four shoots of 10 trees and the size was determined. Also, data collectors were placed climatic conditions. Fluctuation data population were obtained from 4 years, with significant differences between years ($p \leq 0.05$), it was observed an increase in the average capture, with 2022 being the year with the highest incidence of the psyllid in terms of captures. No monthly abundance pattern is observed in the sampling years; behavior galore changed every year; which caused the significant differences ($p \leq 0.05$). In the sampling years it was observed significant correlation between average abundance and average temperature ($p \leq 0.05$). Through a Sperman correlation, it was observed that the outbreak scales have a low correlation in relation to the abundance of nymphs and adults; However, an association of nymph abundance with the scale was observed. Of shoots 3; while adults are significantly associated with outbreaks 7.

**Citricultura, Monitoreo, Plaga, Fluctuación**

**Resumen**

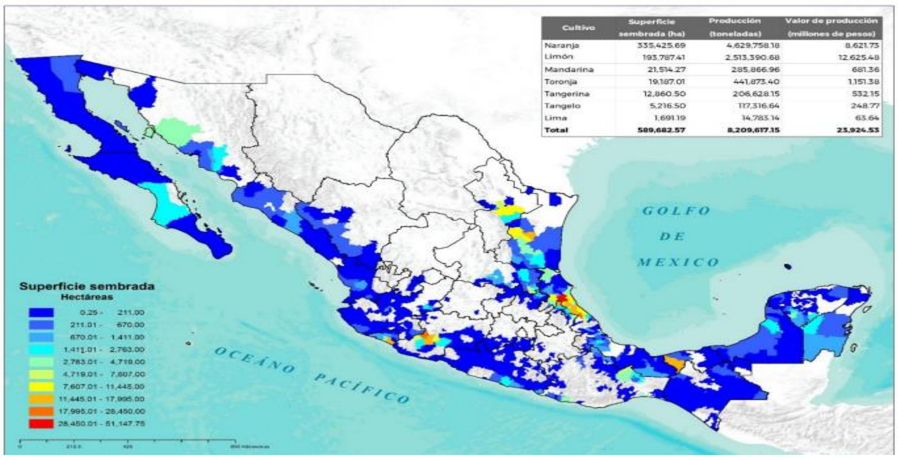
El psílido asiático de los cítricos *Diaphorina citri* Kuwayama, en complejo con la bacteria fitopatógena *Candidatus liberibacter asiaticus*, causa la enfermedad Huanglongbing que afecta la producción de cítricos en México, ubicado entre los principales productores de limón, naranja y mandarina. Así, la citricultura se encuentra en serios problemas. Asociar las variables ambientales y las condiciones del sitio con la incidencia del psílido. Se colocaron 20 trampas amarillas en cinco huertos de naranja. Se registró el número de adultos y ninfas en cuatro brotes de 10 árboles y se determinó su tamaño. También se colocaron colectores de datos sobre las condiciones climáticas. Se obtuvieron datos de fluctuación poblacional de 4 años, con diferencias significativas entre años ($p \leq 0,05$), se observó un incremento en la captura media, siendo 2022 el año con mayor incidencia del psílido en cuanto a capturas. No se observa un patrón de abundancia mensual en los años de muestreo; el comportamiento galore cambió cada año; lo que ocasionó las diferencias significativas ($p \leq 0,05$). En los años de muestreo se observó correlación significativa entre la abundancia media y la temperatura media ($p \leq 0,05$). A través de una correlación de Sperman, se observó que las escamas de los brotes tienen una baja correlación en relación a la abundancia de ninfas y adultos; Sin embargo, se observó una asociación de la abundancia de ninfas con la escama. De brotes 3; mientras que los adultos se asocian significativamente con los brotes 7.

**Citricultura, Monitoreo, Plaga, Fluctuación**

## 5 Introduction

In Mexico, citriculture is one of the most economically important fruit growing activities and also positions the country among the first places in citrus production, with a reported surface area of 526 thousand hectares of citrus, distributed in 23 states of the Mexican Republic, with a production of 6.7 million tonnes per year, and a value of more than 8 billion 50 million pesos (Martínez, 2009). In 2015, oranges ranked first with a production of almost 4 million tonnes, with the states of Veracruz, Tamaulipas and San Luis Potosí accounting for 67 % of the production harvested nationally (Ministry of Agriculture and Rural Development, 2017). However, despite the aforementioned importance, citriculture is seriously threatened by various pests, among which the Asian citrus psyllid (*Diaphorina citri*) (Baños et al., 2015) associated with the bacterium *Candidatus liberibacter* which together cause the Huanglongbing disease (HLB), one of the most important worldwide (Mora et al., 2014) and for which there is a phytosanitary campaign focused on control in all the states with citrus production (Fig. 1) (NOM-EM-047-FITO-2009).

**Figure 5** Map of the main citrus producing areas in Mexico




Source: (SIAP, 2018)

Despite the control efforts that have been made to control the pest, damage to diseased trees cannot be cured and they eventually die after a few years, during which time their development capacity is reduced, they produce small, deformed and tasteless fruit, inverted ripening, seed abortion, as well as mottled leaves and the appearance of yellow shoots (Ortega et al., 2013 and SAGARPA, 2014).

In Querétaro, citriculture is under protection due to the detection of the HLB bacterium in samples of the psyllids, and together with activities such as the application of mineral oil, biological control with Tamarixia radiata Waterston and fortnightly monitoring, the population of the Asian citrus psyllid is kept low (CESAVEQ, 2021). citri, these activities are also replicated in the Concá area in order to reduce production costs in commercial orchards as well as in backyard orchards (Government of Mexico, 2021).

In the state of Querétaro there is a first record of the Asian psyllid in the municipality of Arroyo Seco, Querétaro, this report was made in April 2004, since then sampling and censuses have been carried out to delimit the presence of the pest and according to the secretary of the EPPO it is the first record in the state of Querétaro (EPPO, 2004). Although historical data on the beginning of citrus cultivation and the spread of the Asian citrus psyllid are unknown, in 2013 the citrus psyllid control campaign was initiated and 270 hectares of citrus were registered (Table 5).

**Table 5** Distribution of citrus crops with phytosanitary management in the state of Querétaro

| Crop | Municipality | Surface (Ha) | Production (ton) | Value of production ($) |
|---|---|---|---|---|
| Lemon | Jalpan de Serra | 13.00 | 104.00 | 208,000.00 |
| | Landa de Matamoros | 0.75 | 6.00 | 12,000.00 |
| Lemon | Landa de Matamoros | 6.25 | 50.00 | 100,000.00 |
| Orange | Arroyo Seco | 33.75 | 317.25 | 634,500.00 |
| | Landa de Matamoros | 0.25 | 2.00 | 4000.00 |
| Orange | Arroyo Seco | 161.25 | 1293.36 | 2,586,718.64 |
| | Pinal de Amoles | 4.25 | 0 | 0.00 |
| | Jalpan de Serra | 24.50 | 196 | 392,000.00 |
| | Total | 244.00 | 1968.61 | 3,937,218.64 |

*Source: Government of Mexico, 2013*

The Asian citrus psyllid causes a great number of damages in plants of the Rutaceae family, (Ortega et al., 2013; Alemán, 2007), derived from its preference for this family, in nymph stage it feeds on the sap of the plant as well as buds and young leaves (Baños et al., 2015), while injecting the HLB bacteria (Huanglongbing) from one plant to others (Hernández, et al., 2013; García, 2013 and Díaz et al., 2014)), as well as causing dwarfing, death of vegetative shoots and even of the tree, which is why constant epidemiological surveillance is carried out in commercial and backyard orchards, as well as the elimination of HLB-positive plants (Yzquierdo et al., 2021).

## 5.1 Methodology

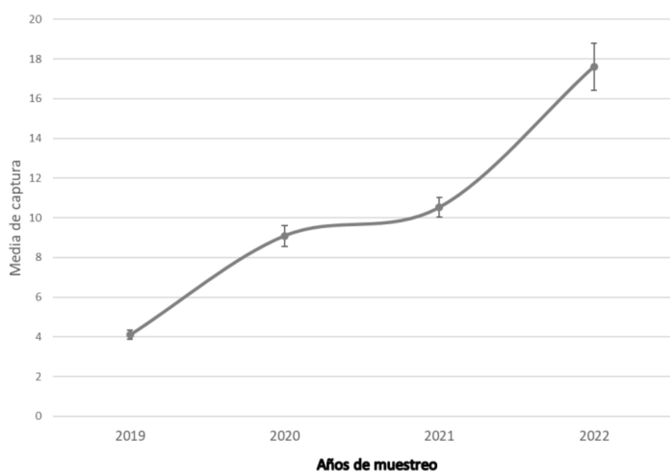
Therefore, a collaboration agreement was signed with the State Plant Health Committee of Querétaro (CESAVEQ) to evaluate the psyllid control strategy within the phytosanitary campaign for the control of the Asian citrus psyllid. The methodology proposed by CESAVEQ, 2021 in the operation manual for citrus regulatory pests was followed. In each orchard 20 yellow sticky traps were placed, gridded on both sides, measuring 12.5x17.5 cm, with a separation of 10 metres between each trap, facing north-west at a height of approximately two metres above ground level. The traps were numbered from 1 to 20 and labelled with the date of placement.

Every 15 days the traps were replaced and the number of adult psyllids collected in each trap was counted, then the number of adults captured and the phenological stage of the trees was recorded using the SIMDIA-Mobile (Smartphone) application (Diaphorina monitoring system), the replaced traps were transferred in a cooler to the laboratory of Management and Conservation of Natural Resources CIDAF-UAQ where the adults stuck and captured in the traps were detached with the help of a brush dipped in 96% alcohol and preserved in bottles with 70% alcohol for corroboration of the identification and subsequent assembly. For the association of the developmental stages of the psyllid and the phenological stages of the shoots, the number of adults and nymphs was recorded in four shoots in 10 trees and the size of each shoot was determined according to the scale proposed by INIFAP and climatic data collectors were placed. The climatic data were obtained by data logger in each of the orchards.

## 5.2 Results and discussion

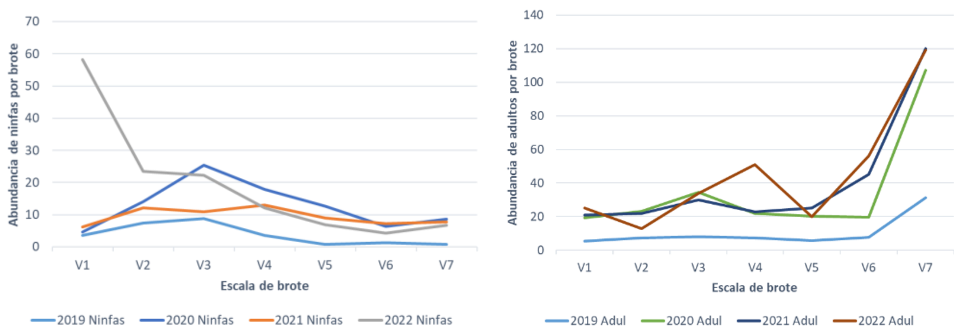
Sampling was carried out from 2019 to 2022, with significant differences between years ($p = <0.05$), (Fig. 5.1). An increase in the mean number of captures was observed, with 2022 being the year with the highest incidence of the psyllid in terms of captures. No monthly abundance pattern was observed in the sampling years, the behaviour in terms of abundance changed each year with significant differences ($p = < 0.05$). In 2019 two abundance peaks were observed in July and September, in 2020 the highest abundance was recorded in March, for 2021 May was the month with the highest average abundance, and April recorded the highest averages of psilids in 2022. Significant correlation between average abundance and average temperature was observed in the sampling years ($p = <0.05$). These data show that the fluctuation of *D. citri* is not homogeneous and depends on environmental factors and orchard conditions.

**Figure 5.1** *D. citri* sampling years in the orange-growing area of Querétaro




Temperature is an environmental factor that favours high incidences of the psyllid in the sampled orchards. On the other hand, an important correlation was observed between stage 2 and 3 nymphs with category 3 outbreaks, while adults were perfectly associated with category 7 outbreaks (Fig. 5.2).

**Figure 5.2** Association of nymphs and adults in relation to outbreak scale.




*D. citri* is present all year round, it is possible that its multivoltine biology allows it to have several generations per year and therefore to be present all year round. The year 2022 was the year with the highest abundance of the psyllid, however, in 2019 two population peaks were observed. From 2020 to 2022, population peaks were observed in March, April and May, contrary to what was reported by Luna-Cruz et. al., 2018. However, this behaviour is reported by García-Garduzca et. al., 2013. There is a significant correlation with temperature, coinciding with that reported by Hernández-Fuentes et. al., 2022. An association was observed between scale 7 shoots with adults and scale 1 and 3 tender shoots with *D. citri* nymphs. More precise statistics are needed and the phenology of the plant needs to be taken into account.

### 5.3 Conclusions

It was observed that Diaphorina citri does not have a pattern of population fluctuation, possibly due to its multivoltine biology, in addition the populations of the psyllid have increased notably in recent years and finally an association was determined between the tender vegetative shoots and the nymphal stages, possibly due to the type of feeding that the psyllid has, likewise the adults are associated with mature shoots, possibly occupying them as breeding sites.

### 5.4 Acknowledgements

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### 5.5 References

Alemán, J., Baños, H. & Ravelo, J. (2007). Diaphorina citri y la enfermedad Huanglongbing: Una combinación destructiva para la producción citrícola. Revista de Protección Vegetal. Vol. 22 (3), pp: 154-155.

Baños, H.L., Miranda, I., Rodríguez, H., Sánchez C., Chico, R. y Martínez M. (2015). Parámetros poblacionales de Diaphorina citri Kuwayama (Hemiptera: Liviidae) y Tamarixia radiata Waterston (Hymenoptera: Eulophidae) en condiciones naturales. Vol. 30 (1), pp: 30-39.

Comité Estatal de Sanidad Vegetal Querétaro (CESAVEQ). (2021). Campaña contra el Huanglongbing de los Cítricos en el Estado de Querétaro.

Díaz, G., López, J., Sánchez, I., Guajardo, R., Mora, G., y Quijano, J. (2014). Áreas de abundancia potencial en México del vector del Huanglongbing, Diaphorina citri (Hemiptera: Liviidae). Revista Mexicana de Ciencias Agrícolas, 5 (7), 1137.

EPPO (Organización Europea y Mediterránea de Protección de las Plantas). (2004). Primer reporte de Diaphorina citri en México. Disponible en línea: https://gd.eppo.int/reporting/article-1625

García, F. (2013). Caracterización morfométrica y genética de Diaphorina citri (Hemiptera: Liviidae) de rutáceas en Cazones, Veracruz, México. Colegio de Postgraduados.

García, D., Sánchez, S., Romero, J. y Pérez, J. (2013). Fluctuación poblacional de Diaphorina citri (Hemiptera: Liviidae) en limón persa (Citrus latifolia), en Huimanguillo, Tabasco, México.

Gobierno de México. (2021). Programa de trabajo integral del subcomponente servicios fitosanitario en apoyo a la producción para el bienestar y prevención, control o erradicación de plagas fitosanitarias en del estado de Querétaro, del programa de Sanidad e Inocuidad Agroalimentaria ejercicio fiscal 2021, con recursos de origen Federal.

Hernández, L., López, J., García, C., Osorio, F., & Nava, M. (2013). Dinámica espacio-temporal de Diaphorina citri Kuwayama (Hemiptera: Psyllidae) en Murraya paniculata (l.) Jack en Cuitláhuac, Veracruz. Acta Zoológica Mexicana. 29(2), 334-345.

Hernández-Fuentes, L. M., Isiorda-Aquino, N., Urias-López, M. A., Luna-Esquivel, G., & Velázquez-Monreal, J. J. (2022). Spatio-temporal distribution of Diaphorina citri Kuwayama adults on Citrus latifolia in Nayarit, Mexico: Implications for regional management. Revista Colombiana de Entomología, 48(2).

Luna, A., Escamilla, J. J., Barreda S. G. & Loera, E. (2018). Fluctuación poblacional de Diaphorina citri Kuwayama (Hemiptera: Liviidae) en el valle de Apatzingán, Michoacán. Acta Zoológica Mexicana (nueva serie), 34, 1–4.

Martínez M. J., J.E. Padrón Ch. 2009. Establecimiento de la huerta. pp. 27-55. En: Rocha-Peña, M. A., y Padrón-Chávez, J. E. (Eds.). El cultivo de los cítricos en el estado de Nuevo León. Libro científico No. 1. Instituto nacional de Investigaciones Forestales, Agrícolas y Pecuarias. CIRNE. Campo Experimental General Terán. México.

NOM-EM-047-FITO-2009. (2009). NORMA Oficial Mexicana de Emergencia NOM-EM-047-FITO-2009, Por la que se establecen las acciones fitosanitarias para mitigar el riesgo de introducción y dispersión del Huanglongbing (HLB) de los cítricos (Candidatus liberibacter spp.) en el territorio nacional. Diario Oficial de la Federación. 2 de julio de 2009.

Ortega, LD, Villegas, Á., Ramírez, AJ, & Mendoza, EE (2013). Abundancia estacional de Diaphorina citri (Hemiptera: Liviidae) en plantaciones de cítricos en Cazones, Veracruz, México. Acta Zoológica Mexicana, 29 (2),317- 333.

Secretaria de Agricultura y Desarrollo Rural. (2017). Se consolida México como quinto productor mundial de naranja. Recuperado de: https://www.gob.mx/agricultura/prensa/se-consolida-mexico-como-quinto-productor-mundial-de-naranja

Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación(SAGARPA). (2014). El Psílido Asiático de los Cítricos Diaphorina citri y su manejo en la zona media y Huasteca potosina.

Yzquierdo, ME, Rincón, JA, Loeza, E., López, JF, Aceves, LA, y Ortiz, CF (2021). Fluctuación espacio-temporal de Diaphorina citri Kuwayama (Hemiptera: Liviidae) en limón persa (Citrus latifolia) en la zona citrícola de Huimanguillo, Tabasco. Acta Zoológica Mexicana (NS), 1-14

# Chapter 6 Sustainable Aquaculture, what should we consider?

# Capítulo 6 Acuicultura sustentable, ¿Qué debemos considerar?

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**Abstract**

In recent decades, aquaculture has played a crucial role in global food security by meeting the increasing demand for high-quality animal protein. Mexico engages in aquaculture across 23 of its 32 states, producing 351,002 tons of aquaculture products in 2021. However, disparities exist between large and small producers due to financial constraints, technological limitations, and the impact of climate change. Despite aquaculture's contribution to meeting protein demands, sustainability concerns persist. The constant increase in aquaculture demand, coupled with the generation of waste and negative public perceptions, presents challenges. Key issues include parasites in farms, antibiotic use, sourcing aquaculture feed, nutrient release, waste accumulation, and the impact on wild populations and introduction of non-native species. The article proposes solutions for sustainable aquaculture, focusing on recent advancements. Various approaches are discussed, including integrated control programs involving chemical, biological, and mechanical methods, proper antibiotic management, exploration of alternative protein sources, and the reduction of excess nutrient release and waste in natural ecosystems through integrated approaches like agroaquaculture and integrated multitrophic aquaculture. The aim is to minimize the impact on wild populations and prevent the introduction of non-native species. Strategies such as diversifying cultivated species and prioritizing regional suitability are also recommended. In conclusion, achieving sustainability in aquaculture involves minimizing waste, promoting local production, and adopting practices that consider ecological balance. The adoption of sustainable practices, such as species diversification and integrated multitrophic aquaculture, along with effective parasite and disease management, is crucial for the long-term viability of the aquaculture industry. Public awareness and education are also essential to garner societal acceptance and support for sustainable aquaculture practices.

**Sustainable aquaculture, Integral aquaculture, Multi-trophic aquaculture, Agro-aquaculture**

**Resumen**

En las últimas décadas, la acuicultura ha desempeñado un papel crucial en la seguridad alimentaria global al satisfacer la creciente demanda de proteína animal de alta calidad. México participa en la acuicultura en 23 de sus 32 estados, produciendo 351,002 toneladas de productos acuícolas en 2021. Sin embargo, existen disparidades entre los grandes y pequeños productores debido a limitaciones financieras, restricciones tecnológicas y el impacto del cambio climático. A pesar de la contribución de la acuicultura para satisfacer las demandas de proteínas, persisten preocupaciones sobre la sostenibilidad de esta. El constante aumento en la demanda de productos acuícolas, junto con la generación de residuos y las percepciones negativas del público, presentan un gran desafío. Problemas clave incluyen la presencia de parásitos en las granjas, el uso de antibióticos, la obtención de alimentos para la acuicultura, la liberación de nutrientes, la acumulación de residuos y el impacto en poblaciones silvestres e introducción de especies no autóctonas. El artículo propone soluciones para la acuicultura sostenible centradas en avances recientes. Se discuten diversas estrategias, tales como programas ide control integrados que involucran métodos químicos, biológicos y mecánicos, manejo adecuado de antibióticos, exploración de fuentes alternativas de proteínas y reducción de la liberación excesiva de nutrientes y residuos en ecosistemas naturales mediante enfoques integrales como la agroacuicultura y la acuicultura multitrófica integrada. El objetivo es minimizar el impacto en poblaciones silvestres y prevenir la introducción de especies no autóctonas. También se recomiendan estrategias como la diversificación de las especies cultivadas y la priorización de la producción localizada. En conclusión, lograr la sostenibilidad en la acuicultura implica minimizar residuos, promover la producción local y adoptar prácticas que consideren el equilibrio ecológico. La adopción de prácticas sostenibles, como la diversificación de especies y la acuicultura multitrófica integrada, junto con un manejo efectivo de parásitos y enfermedades, es crucial para la viabilidad a largo plazo de la industria acuícola. La conciencia pública y la educación son también esenciales para obtener aceptación y apoyo social para lograr una producción acuícola sostenible.

**Acuicultura sustentable, Acuicultura integral, Acuicultura multitrófica, Agroacuicultura**

## 6 Introduction

In recent decades, aquaculture has played a key role in global food security by meeting the growing demand for high-quality animal protein. In addition to providing protein, aquaculture provides other essential nutrients, such as fatty acids, amino acids, vitamins and elements such as iodine and selenium, which are often scarce in other crops or meats (Kwasek et al., 2020; Nasr-Eldahan et al., 2021).

In Mexico, aquaculture is present in 23 of the country's 32 states, producing 351,002 tonnes of aquaculture products in 2021. During that year, shrimp led the production with 214,546 tonnes, with a value of $15,330 million pesos. It was followed by mojarra with 96,977 tonnes and a value of $2,588 million pesos, and oyster with 15,602 tonnes and a value of $141 million pesos (CONAPESCA, 2021). It should be noted that these data come from the 4,845 registered production units, but it is estimated that most production systems are small and are not registered, which could distort the statistics (Ortega-Mejía et al., 2023).

In general, aquaculture production is concentrated among a small number of large producers, who account for more than 70% of production, while small producers cover less than 30% (Hasimuna et al., 2023). This disparity is attributed to lack of financial resources among small-scale producers, as well as poor technology implementation, poor management of material resources, limited access to adequate markets and the effects of climate change (Hasimuna et al., 2023; Maulu et al., 2021; Ortega-Mejía et al., 2023).

The aquaculture sector faces constant uncertainty regarding its sustainability, as demand for aquaculture products continues to increase, with per capita consumption exceeding 20 kg. This has led aquaculture to contribute 56% of the production of aquatic organisms for human consumption (FAO, 2022). The growth in production also leads to an increase in waste generation, which affects both the productivity of aquaculture systems and natural aquatic ecosystems (Nasr-Eldahan et al., 2021). Despite increasing demand, aquaculture production is often perceived negatively by society (Correia et al., 2020), which hinders the implementation of sustainable production systems. Therefore, it is essential to address the main problems associated with aquaculture, which have been identified in previous studies (Correia et al., 2020; Hasimuna et al., 2023; Mangano et al., 2019; Ortega-Mejía et al., 2023; van Osch et al., 2017):

- The presence of parasites in aquaculture farms and the use of antibiotics to increase productivity and prevent diseases.
- The supply of feed for aquaculture.
- The excessive release of nutrients into natural ecosystems and the accumulation of aquaculture waste in natural water bodies.
- The impact of aquaculture on wild populations and the introduction of non-native species.

Each of these problems has specific contexts, and this paper will provide a general introduction to them, summarising the main proposals for addressing the challenges that stand in the way of achieving sustainable aquaculture. The main purpose of the paper is to encourage new proposals for solutions that promote true sustainability in aquaculture.

### 6.1 Methodology to be developed

Sustainability in aquaculture has become an issue of great relevance in recent years. Numerous studies have been carried out to propose methodologies to reduce the environmental impact of aquaculture and improve its resource efficiency. However, there has been less research focused on the dissemination of production alternatives that promote more sustainable aquaculture with less impact on aquatic ecosystems. Therefore, this article is based on a focused literature review, using search tools and browsers such as Google Scholar to obtain a wide range of results. The most recent studies were prioritised, and search terms included "integrated aquaculture", "sustainable aquaculture", "multi-trophic aquaculture", "agro-aquaculture", "polyculture", among others.

The content of the articles was reviewed for direct or indirect relevance to this paper, and relevant references found in some of the reviewed studies were also included. Some studies were not included if they did not meet adequate standards of project design or data management, in order to avoid introducing biased information.

**6.2 Results**

In order to address the main issues in aquaculture, multiple solutions have been proposed and investigated both theoretically and experimentally. In this paper, only the most recent and most interesting solution proposals for the specialised community will be presented, providing a brief context of the problem in question.

*6.2.1 The presence of parasites in aquaculture farms and the use of antibiotics to increase productivity and prevent diseases*

One of the predominant challenges in any type of aquaculture culture is the presence of parasites associated with the species. In their natural habitat, organisms harbour a number of parasites, but the problem is that some of these tend to spread rapidly under aquaculture culture conditions (Buchmann, 2022). This accelerated spread not only reduces productivity, but also poses the risk of transmitting diseases to organisms in the production system and to wild species in the environment (Bouwmeester et al., 2021). Due to their high adaptability, the main approach to control parasites is the implementation of integrated control programmes encompassing chemical treatments, medication, biological and mechanical systems. This is done to reduce the risk of developing resistance, as to date no specific method has been documented that can completely control parasite proliferation (Buchmann, 2022; Buchmann et al., 2022).

On the other hand, in the same context, antibiotics are widely used to prevent bacterial infections and improve growth and productivity (Mo et al., 2017; Noor et al., 2023). However, due to inadequate waste management in the environment, resistance has been induced in the microbial community in the environment (Noor et al., 2023). To address this problem, some countries have implemented restrictions on the use of chemotherapeutic agents (Correia et al., 2020). Proposals have also been developed to degrade antibiotics using various methodologies (Gong et al., 2023; Noor et al., 2023; Silva et al., 2021). Considering the quest for sustainable aquaculture, the preventive rather than the corrective approach should be prioritised. Therefore, proper use and management of antibiotics represents the best alternative to control this problem.

*6.2.2 The aquaculture feed source*

One of the main concerns regarding the sustainability of aquaculture lies in its reliance on fishmeal as the main source of protein in the feed of aquaculture organisms to achieve the desired productivity (Kari et al., 2022). Despite decades of research on the use of alternative protein sources, a viable alternative has so far not been found due to its practicality and feasibility (Kari et al., 2022; Wang et al., 2023).

To address this problem, the main focus is on reducing the use of fishmeal and fish oils in aquaculture feed production (Gatlin III et al., 2007; Idenyi et al., 2022; Moutinho et al., 2017). This has been achieved by exploring alternative feeds, including algae, microorganisms, insects and agricultural wastes, among others (Eroldoğan et al., 2023; Howieson et al., 2023; Kari et al., 2022; Ratti et al., 2023; Wang et al., 2023). In addition, research and the use of additives to improve growth and feed efficiency, as well as to strengthen the immune system and increase resistance to disease (Azeredo et al., 2017; Magalhães et al., 2016) has been promoted, which could lead to a direct reduction in feed consumption. Importantly, further research into alternative protein sources for aquafeeds is needed to achieve long-term sustainability of aquaculture production systems.

*6.2.3 Excess nutrients released into natural ecosystems and the accumulation of aquaculture waste in natural water bodies*

Despite efforts to find technological solutions to improve the sustainability of aquaculture, intensive production systems release high levels of nutrients and organic wastes that can cause eutrophication of natural aquatic systems (Sarà et al., 2018). Only about 20-40% of the nitrogen and less than 50% of the calories consumed are retained by the farmed species (Correia et al., 2020; Peres and Oliva-Teles, 2005; Teles et al., 2020). The generation of waste represents one of the main problems that cause uncertainty and consumer rejection of aquaculture production (Hasimuna et al., 2023). There are various proposals to reduce nutrient accumulation, including integrated production in its various forms. These include agro-aquaculture systems, crop-livestock-fish farming systems and multi-trophic or polyculture systems (Buck et al., 2018; Hasimuna et al., 2023; Thomas et al., 2021; Waktola et al., 2016).

Agro-aquaculture systems are characterised by interdependence between their components, allowing them to meet human requirements while reducing their impact on the environment (Hasimuna et al., 2023). These systems can be configured in different ways: aquafeed grown in combination with plants, livestock or other animals in the same production system, or the independent cultivation of each system within the same farm, using waste from one as input for the other. This provides a portion of the requirements for quality food production at low cost, in addition to generating employment and a source of household income (Hasimuna et al., 2023). This production model allows smallholders to generate steady income from different production systems within their farm (Hasimuna et al., 2023). As this model represents one of the best alternatives to increase the income of small-scale farmers, it should be encouraged (Ibrahim et al., 2023).

Integrated multi-trophic aquaculture (AMTI) is a strategy that seeks to integrate the production of aquaculture species at different trophic levels under a circular economy approach. It aims to minimise energy losses and reduce environmental degradation (Buck et al., 2018; Correia et al., 2020). In this production system, uneaten food and waste from one species is recaptured and converted into food, fertiliser and energy for other species. AMTI has the potential to promote sustainability in aquaculture with environmental, economic and social advantages (Correia et al., 2020; Khanjani et al., 2022). This is achieved through nutrient recirculation, which increases economic resilience by improving productivity, diversifying products and the possibility of accessing markets willing to pay a better price due to the commitment to the environment. (Correia *et al*., 2020; van Osch *et al*., 2017).

AMTI can be implemented in various configurations, including vertebrate, invertebrate and algal production. In this system, organisms that are fed and species that extract organic and inorganic substances from the water are included (Khanjani et al., 2022). In freshwater aquaculture systems, rearing species may include, for example, tilapia (Klahan et al., 2023), while species that feed on organic waste, such as uneaten food and faeces, may be species such as freshwater prawns or catfish (Nuswantoro et al., 2023). In addition, microalgae, which capture dissolved nutrients, also play a role in this system (Idenyi et al., 2022).

Ecological processes in polyculture systems also involve associated biodiversity, which includes wild fish, plants, invertebrates, microorganisms and terrestrial animals (Thomas et al., 2021). AMTI systems encourage more sustainable aquaculture by considering different species as valuable products rather than problems, which optimises resource use, promotes economic diversification and improves social acceptance through better management.

*6.2.4 The impact of aquaculture on wild populations and the introduction of non-native species is a major issue in the management of these systems.*

Aquaculture has been identified as a significant mechanism for the introduction of non-native species into freshwater aquaculture ecosystems (Gu et al., 2022). Although many of the species of commercial interest have failed to establish in new environments, aquaculture has been directly or indirectly linked to the introduction of non-native species with the potential to become invasive (Sandilyan, 2023). These non-native species that manage to establish in the natural environment due to escapes or poor aquaculture farm management represent a direct threat to regional biodiversity due to competition for resources with native species (Kang et al., 2023; Peña-Herrejón et al., 2016; Thomas et al., 2021).

A viable alternative to reduce the risk that aquaculture poses to biodiversity is the diversification of cultivable species (Bernery et al., 2023; Thomas et al., 2021). This strategy involves prioritising the use of regional species that can be cultivated in aquaculture systems, thus promoting localised production. By focusing on species that already have a potential to thrive in the environment, the likelihood of introducing non-native species into natural ecosystems is reduced, which contributes to the conservation of local biodiversity (Hasimuna et al., 2023; Peña-Herrejón et al., 2016).

In summary, diversification of cultivable species and a focus on regional species are key strategies to minimise the impact of aquaculture on wild populations and reduce the risk of introducing non-native species into freshwater aquaculture ecosystems. These measures are essential to preserve biodiversity and ensure the long-term sustainability of aquaculture.

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### 6.4 Conclusions

In the quest for sustainability in aquaculture, it is imperative to focus on minimising waste and promoting local production. The adoption of more sustainable aquaculture practices not only reduces social opposition to intensive aquaculture, but also promotes the conservation of natural resources and community welfare. In order to achieve sustainable aquaculture, it is essential to convey clear and accessible information about the advantages and opportunities offered by this form of production (Buck et al., 2018; Correia et al., 2020).

In short, sustainability in aquaculture is not only a desirable goal, but a necessity. The adoption of sustainable practices, such as the diversification of farmable species, the implementation of AMTI systems and the proper management of parasites and diseases, is essential to ensure the health of aquaculture ecosystems and the long-term viability of the industry. In addition, promotion of local production and education about the benefits of sustainable aquaculture are crucial steps to ensure societal acceptance and continued support.

### 6.5 References

Azeredo, R., Machado, M., Afonso, A., Fierro-Castro, C., Reyes-López, F. E., Tort, L., Gesto, M., Conde-Sieira, M., Míguez, J. M., Soengas, J. L., Kreuz, E., Wuertz, S., Peres, H., Oliva-Teles, A., y Costas, B. (2017). Neuroendocrine and Immune Responses Undertake Different Fates following Tryptophan or Methionine Dietary Treatment: Tales from a Teleost Model. Frontiers in Immunology, 8. https://www.frontiersin.org/articles/10.3389/fimmu.2017.01226

Bernery, C., Marino, C., y Bellard, C. (2023). Relative importance of exotic species traits in determining invasiveness across levels of establishment: Example of freshwater fish. Functional Ecology, 37(9), 2358–2370. https://doi.org/10.1111/1365-2435.14393

Bouwmeester, M. M., Goedknegt, M. A., Poulin, R., y Thieltges, D. W. (2021). Collateral diseases: Aquaculture impacts on wildlife infections. Journal of Applied Ecology, 58(3), 453–464. https://doi.org/10.1111/1365-2664.13775

Buchmann, K. (2022). Control of parasitic diseases in aquaculture. Parasitology, 149(14), 1985–1997. https://doi.org/10.1017/S0031182022001093

Buchmann, K., Nielsen, T., Mathiessen, H., Marana, M. H., Duan, Y., Jørgensen, L. V. G., Zuo, S., Karami, A. M., y Kania, P. W. (2022). Validation of two QTL associated with lower Ichthyophthirius multifiliis infection and delayed-time-to-death in rainbow trout. Aquaculture Reports, 23, 101078. https://doi.org/10.1016/j.aqrep.2022.101078

Buck, B. H., Troell, M. F., Krause, G., Angel, D. L., Grote, B., y Chopin, T. (2018). State of the Art and Challenges for Offshore Integrated Multi-Trophic Aquaculture (IMTA). Frontiers in Marine Science, 5. https://www.frontiersin.org/articles/10.3389/fmars.2018.00165

CONAPESCA. (2021). ANUARIO ESTADÍSTICO DE ACUACULTURA Y PESCA 2021. SADER. https://nube.conapesca.gob.mx/sites/cona/dgppe/2021/ANUARIO_ESTADISTICO_DE_ACUACULTURA_Y_PESCA_2021.pdf

Correia, M., Azevedo, I. C., Peres, H., Magalhães, R., Oliva-Teles, A., Almeida, C. M. R., y Guimarães, L. (2020). Integrated Multi-Trophic Aquaculture: A Laboratory and Hands-on Experimental Activity to Promote Environmental Sustainability Awareness and Value of Aquaculture Products. Frontiers in Marine Science, 7. https://www.frontiersin.org/articles/10.3389/fmars.2020.00156

Eroldoğan, O. T., Glencross, B., Novoveska, L., Gaudêncio, S. P., Rinkevich, B., Varese, G. C., de Fátima Carvalho, M., Tasdemir, D., Safarik, I., Nielsen, S. L., Rebours, C., Lada, L. B., Robbens, J., Strode, E., Haznedaroğlu, B. Z., Kotta, J., Evliyaoğlu, E., Oliveira, J., Girão, M., … Rotter, A. (2023). From the sea to aquafeed: A perspective overview. Reviews in Aquaculture, 15(3), 1028–1057. https://doi.org/10.1111/raq.12740

FAO. (2022). The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation. FAO. https://doi.org/10.4060/cc0461en

Gatlin III, D. M., Barrows, F. T., Brown, P., Dabrowski, K., Gaylord, T. G., Hardy, R. W., Herman, E., Hu, G., Krogdahl, Å., Nelson, R., Overturf, K., Rust, M., Sealey, W., Skonberg, D., J Souza, E., Stone, D., Wilson, R., y Wurtele, E. (2007). Expanding the utilization of sustainable plant products in aquafeeds: A review. Aquaculture Research, 38(6), 551–579. https://doi.org/10.1111/j.1365-2109.2007.01704.x

Gong, H., Li, R., Zhang, Y., Xu, L., Gan, L., Pan, L., Liang, M., Yang, X., Chu, W., Gao, Y., y Yan, M. (2023). Occurrence and removal of antibiotics from aquaculture wastewater by solar-driven Fe(VI)/oxone process. Chemosphere, 340, 139809. https://doi.org/10.1016/j.chemosphere.2023.139809
Gu, D. E., Wang, J. W., Xu, M., Mu, X. D., Wei, H., Yu, F. D., Fang, M., Wang, X. J., Song, H. M., Yang, Y. X., Li, G. J., Cai, X. W., y Hu, Y. C. (2022). Does aquaculture aggravate exotic fish invasions in the rivers of southern China? Aquaculture, 547, 737492. https://doi.org/10.1016/j.aquaculture.2021.737492

Hasimuna, O. J., Maulu, S., Nawanzi, K., Lundu, B., Mphande, J., Phiri, C. J., Kikamba, E., Siankwilimba, E., Siavwapa, S., y Chibesa, M. (2023). Integrated agriculture-aquaculture as an alternative to improving small-scale fish production in Zambia. Frontiers in Sustainable Food Systems, 7. https://www.frontiersin.org/articles/10.3389/fsufs.2023.1161121

Howieson, J., Chaklader, M. R., Chung, W. H., Howieson, J., Chaklader, M. R., y Chung, W. H. (2023). Market-driven assessment of alternate aquafeed ingredients: Seafood waste transformation as a case study. Animal Production Science. https://doi.org/10.1071/AN23064

Ibrahim, L. A., Abu-Hashim, M., Shaghaleh, H., Elsadek, E., Hamad, A. A. A., y Alhaj Hamoud, Y. (2023). A Comprehensive Review of the Multiple Uses of Water in Aquaculture-Integrated Agriculture Based on International and National Experiences. Water, 15(2), Article 2. https://doi.org/10.3390/w15020367

Idenyi, J. N., Eya, J. C., Nwankwegu, A. S., y Nwoba, E. G. (2022). Aquaculture sustainability through alternative dietary ingredients: Microalgal value-added products. Engineering Microbiology, 2(4), 100049. https://doi.org/10.1016/j.engmic.2022.100049

Kang, B., Vitule, J. R. S., Li, S., Shuai, F., Huang, L., Huang, X., Fang, J., Shi, X., Zhu, Y., Xu, D., Yan, Y., y Lou, F. (2023). Introduction of non-native fish for aquaculture in China: A systematic review. Reviews in Aquaculture, 15(2), 676–703. https://doi.org/10.1111/raq.12751

Kari, Z. A., Sukri, S. A. M., Rusli, N. D., Mat, K., Mahmud, M. B., Zakaria, N. N. A., Wee, W., Hamid, N. K. A., Kabir, M. A., Ariff, N. S. N. A., Abidin, S. Z., Zakaria, M. K., Goh, K. W., Khoo, M. I., Doan, H. V., Tahiluddin, A., y Wei, L. S. (2022). Recent Advances, Challenges, Opportunities,Product Development and Sustainability of Main Agricultural Wastes for the Aquaculture Feed Industry – A Review. Annals of Animal Science, 23(1), 25–38. https://doi.org/10.2478/aoas-2022-0082

Khanjani, M. H., Zahedi, S., y Mohammadi, A. (2022). Integrated multitrophic aquaculture (IMTA) as an environmentally friendly system for sustainable aquaculture: Functionality, species, and application of biofloc technology (BFT). Environmental Science and Pollution Research, 29(45), 67513–67531. https://doi.org/10.1007/s11356-022-22371-8

Klahan, R., Yuangsoi, B., Whangchai, N., Ramaraj, R., Unpaprom, Y., Khoo, K. S., Deepanraj, B., y Pimpimol, T. (2023). Biorefining and biotechnology prospects of low-cost fish feed on Red tilapia production with different feeding regime. Chemosphere, 311, 137098. https://doi.org/10.1016/j.chemosphere.2022.137098

Kwasek, K., Thorne-Lyman, A. L., y Phillips, M. (2020). Can human nutrition be improved through better fish feeding practices? A review paper. Critical Reviews in Food Science and Nutrition, 60(22), 3822–3835. https://doi.org/10.1080/10408398.2019.1708698

Magalhães, R., Lopes, T., Martins, N., Díaz-Rosales, P., Couto, A., Pousão-Ferreira, P., Oliva-Teles, A., y Peres, H. (2016). Carbohydrases supplementation increased nutrient utilization in white seabream (Diplodus sargus) juveniles fed high soybean meal diets. Aquaculture, 463, 43–50. https://doi.org/10.1016/j.aquaculture.2016.05.019

Mangano, M. C., Ape, F., y Mirto, S. (2019). The role of two non-indigenous serpulid tube worms in shaping artificial hard substrata communities: Case study of a fish farm in the central Mediterranean Sea. Aquaculture Environment Interactions, 11, 41–51. https://doi.org/10.3354/aei00291

Maulu, S., Hasimuna, O. J., Haambiya, L. H., Monde, C., Musuka, C. G., Makorwa, T. H., Munganga, B. P., Phiri, K. J., y Nsekanabo, J. D. (2021). Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations. Frontiers in Sustainable Food Systems, 5. https://www.frontiersin.org/articles/10.3389/fsufs.2021.609097

Mo, W. Y., Chen, Z., Leung, H. M., y Leung, A. O. W. (2017). Application of veterinary antibiotics in China's aquaculture industry and their potential human health risks. Environmental Science and Pollution Research, 24(10), 8978–8989. https://doi.org/10.1007/s11356-015-5607-z

Moutinho, S., Martínez-Llorens, S., Tomás-Vidal, A., Jover-Cerdá, M., Oliva-Teles, A., y Peres, H. (2017). Meat and bone meal as partial replacement for fish meal in diets for gilthead seabream (Sparus aurata) juveniles: Growth, feed efficiency, amino acid utilization, and economic efficiency. Aquaculture, 468, 271–277. https://doi.org/10.1016/j.aquaculture.2016.10.024

Nasr-Eldahan, S., Nabil-Adam, A., Shreadah, M. A., Maher, A. M., y El-Sayed Ali, T. (2021). A review article on nanotechnology in aquaculture sustainability as a novel tool in fish disease control. Aquaculture International, 29(4), 1459–1480. https://doi.org/10.1007/s10499-021-00677-7

Noor, N. N. M., Hazirah Kamaruzaman, N., Al-Gheethi, A., Maya Saphira Radin Mohamed, R., y Hossain, Md. S. (2023). Degradation of antibiotics in aquaculture wastewater by bio-nanoparticles: A critical review. Ain Shams Engineering Journal, 14(7), 101981. https://doi.org/10.1016/j.asej.2022.101981

Nuswantoro, S., Sung, T.-Y., Kurniawan, M., Wu, T.-M., Chen, B., y Hong, M.-C. (2023). Effects of Phosphate-Enriched Nutrient in the Polyculture of Nile Tilapia and Freshwater Prawn in an Aquaponic System. Fishes, 8(2), Article 2. https://doi.org/10.3390/fishes8020081

Ortega-Mejía, M., Ortega, C., Delgadillo-Tiburcio, S., Martínez-Castañeda, S., y Bautista Gómez, L. (2023). Fresh water fish farming in Mexico: Its current status and factors associated with its production levels. J Aquac Fisheries, 7(57), 2–6.

Peña-Herrejón, G. A., García-Trejo, F., Soto-Zarazúa, G. M., Alatorre-Jácome, O., y Rico-García, E. (2016). First trial of production of a native cichlid Herichthys cyanoguttatus comparison with the tilapia Oreochromis niloticus in aquaculture. Latin American Journal of Aquatic Research, 44(4), 711–717. https://doi.org/10.3856/vol44-issue4-fulltext-6

Peres, H., y Oliva-Teles, A. (2005). Protein and Energy Metabolism of European Seabass (Dicentrarchus labrax) Juveniles and Estimation of Maintenance Requirements. Fish Physiology and Biochemistry, 31(1), 23–31. https://doi.org/10.1007/s10695-005-4586-2

Ratti, S., Zarantoniello, M., Chemello, G., Giammarino, M., Palermo, F. A., Cocci, P., Mosconi, G., Tignani, M. V., Pascon, G., Cardinaletti, G., Pacetti, D., Nartea, A., Parisi, G., Riolo, P., Belloni, A., y Olivotto, I. (2023). Spirulina-enriched Substrate to Rear Black Soldier Fly (Hermetia illucens) Prepupae as Alternative Aquafeed Ingredient for Rainbow Trout (Oncorhynchus mykiss) Diets: Possible Effects on Zootechnical Performances, Gut and Liver Health Status, and Fillet Quality. Animals, 13(1), Article 1. https://doi.org/10.3390/ani13010173

Sandilyan, S. (2023). Do Aquaculture and Ornamental Fish Culturing Sites Act as a Bridgehead for Alien Fish Invasion in Indian Wetlands? A Review. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. https://doi.org/10.1007/s40011-023-01482-3

Sarà, G., Gouhier, T. C., Brigolin, D., Porporato, E. M. D., Mangano, M. C., Mirto, S., Mazzola, A., y Pastres, R. (2018). Predicting shifting sustainability trade-offs in marine finfish aquaculture under climate change. Global Change Biology, 24(8), 3654–3665. https://doi.org/10.1111/gcb.14296

Silva, C. P., Louros, V., Silva, V., Otero, M., y Lima, D. L. D. (2021). Antibiotics in Aquaculture Wastewater: Is It Feasible to Use a Photodegradation-Based Treatment for Their Removal? Toxics, 9(8), Article 8. https://doi.org/10.3390/toxics9080194

Teles, A. O., Couto, A., Enes, P., y Peres, H. (2020). Dietary protein requirements of fish – a meta-analysis. Reviews in Aquaculture, 12(3), 1445–1477. https://doi.org/10.1111/raq.12391

Thomas, M., Pasquet, A., Aubin, J., Nahon, S., y Lecocq, T. (2021). When more is more: Taking advantage of species diversity to move towards sustainable aquaculture. Biological Reviews, 96(2), 767–784. https://doi.org/10.1111/brv.12677

van Osch, S., Hynes, S., O'Higgins, T., Hanley, N., Campbell, D., y Freeman, S. (2017). Estimating the Irish public's willingness to pay for more sustainable salmon produced by integrated multi-trophic aquaculture. Marine Policy, 84, 220–227. https://doi.org/10.1016/j.marpol.2017.07.005

Waktola, B. A., Prabha, D. L., Sreenivasa, V., y Lakew, A. (2016). A Study on the Profitability of Fish and Horticrop Integrated Farming at Nono District, West Shoa Zone, Ethiopia. Greener Journal of Agricultural Sciences, 6(2), 041–048. https://doi.org/10.15580/GJAS.2016.2.112415163

Wang, J., Chen, L., Xu, J., Ma, S., Liang, X., Wei, Z., Li, D., y Xue, M. (2023). C1 gas protein: A potential protein substitute for advancing aquaculture sustainability. Reviews in Aquaculture, 15(3), 1179–1197. https://doi.org/10.1111/raq.12707.

# Chapter 7 Yield and production costs of *Avena sativa* and Vicia faba in the upper Mezquital, Hidalgo

# Capítulo 7 Rendimiento y costos de producción de *Avena sativa* y *Vicia faba* en el alto Mezquital, Hidalgo

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**Abstract**

Forage production is of great importance because it is a livestock input for the nutrition and feeding of the livestock sector. The objective of this project was to evaluate the effect of soil improvers on the yield of Avena sativa and Vicia faba to enhance agricultural productivity in alkaline soils in the upper Mezquital, Hidalgo; in order to ensure livestock feeding in this area. A completely randomized block experimental design was used. The use of organic amendments such as 150 kg ha-1 of manure supplied to the soil favored the biomass yield in oats (13,179 kg ha-1) and it should also be noted that the A-ES treatment reported a lower injection cost ($5,405) and a higher net profit ($11,057). 5), in the bean crop, the supply of organic amendments, minerals and phytohormones favors the yield in this forage, it should be noted that this treatment had a higher investment cost ($6,320) and lower net profit, both compared to the production system of this area. With the above, producers are invited to supply organic matter to the soil to increase the yield in forage productivity.

**Oats, Biomass, Livestock input, Broad bean**

**Resumen**

La produccion de forrajes son de gran importarcia debido a que es un insumo ganadero para la nutrición y alimentacion del sector pecuario. El objetivo del presente proyecto fue evaluar el efecto de mejoradores de suelo sobre el rendimiento de Avena sativa y Vicia faba para potencializar la productividad agrícola en suelos alcalinos en el alto mezquital, Hidalgo; con la finalidad de asegurar la alimentación ganadera en dicha zona. Se utilizo un diseño experimental de bloques completamente al azar. El uso de enmiendas organicas como son los 150 kg ha-1 de estiercol suministrados a el suelo favorecen el rendimiento de biomasa en avena (13,179 kg ha-1) asi mismo cabe señalar que el tratamiento A-ES reporta menor costo de inbercion ($5,405) y mayor ganancia neta ($11,057.5), en el cultivo de haba el suministro de enmiendas organicas, minerales y fitohormonas favorece el rendimiento en dicho forraje, cabe señalar que dicho tratamiento tuvo mayor costo de inversión ($6,320) y menor ganancia neta, abos comparados con el sistema deproducción de dicha zona. Con lo anterior se invita a los productores a suministrar materia organica a el suelo para incrementar el rendimiento en la productividad forrajera

**Avena, Biomasa, Insumo ganadero, Haba**

## 7 Introduction

Fodder is a crop that is used to feed the livestock sector. They can be consumed standing or deferred, depending on the needs of the production process, grass, feed, fodder, hay and silage. Forages are of great importance in livestock feeding due to their high dry matter production and low cost; there are highly adaptable forages that develop in different climatic conditions and low temperatures compared to forage crops such as maize, wheat or barley (Espinoza et al., 2018).

Legumes in animal feed represent an alternative due to their high content of protein, fibre and bioactive compounds. They can be used alone or in mixed crops with grasses. In some regions of the world, there has been a growing interest in the use of fava beans (Vicia faba). In Mexico, fava bean is the third most important grain legume crop in terms of production and is of social, economic and medicinal importance (Díaz and Escalante, 2019). In 2019, 11,500 ha were allocated for green bean cultivation and 19,800 ha for dry grain, with an average yield of 5.5 and 0.7 t-ha-1, respectively (Anonymous, 2019). These low yields are due to the susceptibility of the bean to biotic agents, long vegetative cycle, it is a crop sensitive to lodging, and the characteristics of bean size and colour are only locally accepted; i.e., most producers commonly plant native or traditional cultivars (Morales et al., 2002). Moreover, in traditional production systems, the same cultivar is used for both green pod and dry grain production.  On the other hand, oats (Avena sativa) are of great importance in Mexico, as they are a key input for the production of balanced feed for livestock use, due to the fact that they are an easily managed crop and an alternative that generates high levels of biomass production per hectare with considerable nutritional values and high palatability (Figueroa and Morales, 2023).

This crop has the following advantages: low production costs, adaptability to different climatic zones, annual production, high biomass yields, excellent protein value and digestibility. This type of forage generates positive expectations that open the way to solving the production difficulties of cattle and sheep feed in arid regions (Campuzano et al., 2020). In addition, the objective of this project was to evaluate the effect of soil improvers on the yield of Avena sativa and Vicia faba to enhance agricultural productivity in alkaline soils.

## 7.1 Methodology

The present experiment was carried out in the upper Mezquital area, where an experimental plot was taken as the study area in the ejido El Mezquital, located in the municipality of Santiago de Anaya, Hidalgo at an altitude of 1951 metres above sea level; at a latitude of 20.373056 and a longitude of -99.021111. The experiment was established using a completely randomised block experimental design with the following treatments.

**Table 7** Treatments established in the field

| No. | Abbreviation | Description | Dosage |
|---|---|---|---|
| 1 | A-ES-MIN | Oats, manure and minerals. | 135 kg/ha de ES, 2.5 kg/ha Diat, 11.300 kg/ha microelementos. |
| 2 | A-ES-MIN-FITO | Oats, manure, minerals and phytohormones. | 135 kg/ha de ES, 2.5 kg/ha Diat, 11.300 kg/ha microelementos. |
| 3 | A-ES | Oats with manure. | 150 kg/ha. |
| 4 | T-A | Vein test. | 0 |
| 5 | H-ES-MIN | Faba bean, manure and minerals | 135 kg/ha de ES, 2.5 kg/ha Diat, 11.300 kg/ha microelementos |
| 6 | H-ES-MIN-FITO | Faba bean, manure, minerals and phytohormones. | 135 kg/ha de ES, 2.5 kg/ha Diat, 11.300 kg/ha microelementos. |
| 7 | H-ES | Faba bean, manure | 150 kg/ha. |
| 8 | T- H | Fava bean witness | 0 |

Where: A is Avena sativa, H is Vicia faba, ES refers to manure, MIN is mineral, FITO refers to Fitohormones and T refers to the control.

Fodder oats (Chihuahua variety) were established at a sowing density of 100 kg ha-1. Faba bean with large ball seed at a sowing density of 60,000 thousand seeds ha-1. Green forage sampling of both forages was carried out using the CIMMYT yield determination manual (Verhulst et al., 2012). With the support of the field logbook, activities and production costs during the growing season were recorded. Data were processed with the RStudio software, version 4.2.3 by Tukey's method with 95% probability.

## 7.2 Results and discussion

The oat forage yields presented in Figure 1 show a significant difference (Tukey, $p \leq 0.05$); treatment A-ES obtained 1,302 kg $ha^{-1}$ more than A-ES-MIN-FITO, which benefits the producer's economy by generating higher yields and lower production costs. The lowest yield was obtained by A-T (Control), which refers to the traditional production system. Arias et al., 2021, made high investments in economic and human capital to report an average forage yield of 14,105 kg $ha^{-1}$, which is in the range of production obtained in the A-ES treatment. On the other hand, Rojas and Vega in 1996 state that the application of cattle manure, poultry manure and swine manure raise the dry mass of oats (Avena sativa) and maize (*Zea mays*) to the same levels as a basic fertilization. Figure 7 presents the forage yield of Vicia faba, where significant differences are reported (Tukey, $p \leq 0.05$) between both forages, where it is denoted that the treatment with high yield is H-ES-MIN-FITO with 509 kg ha-1 more than the control which refers to a low yield according to Baizán, Vicente et al., 2018 reports a yield higher than 1475 kg $ha^{-1}$ in the same crop

**Figure 7** Dry biomass yield of Avena Sativa

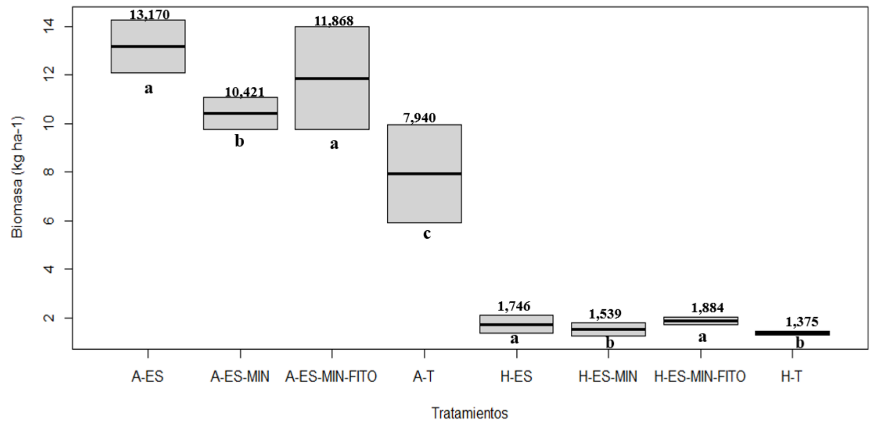
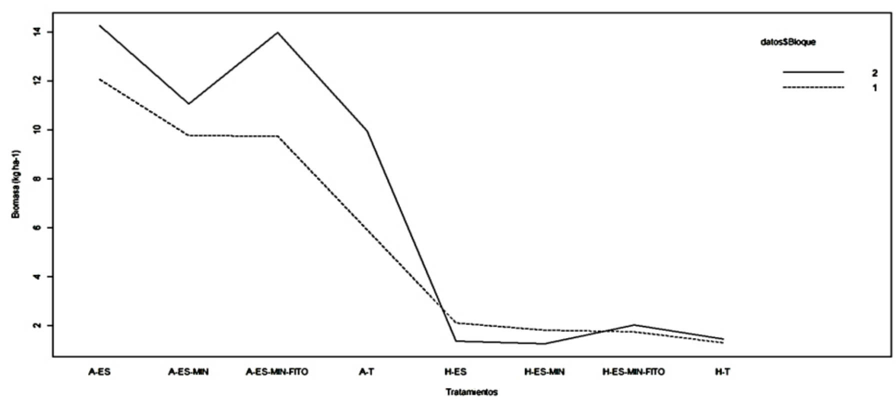


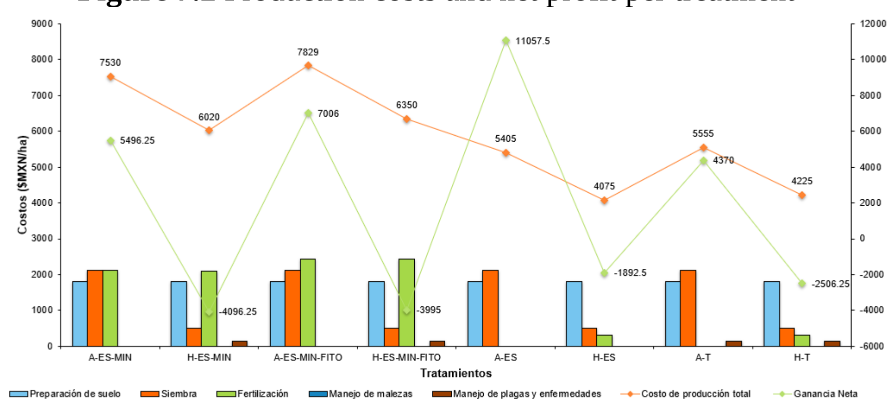

Figure 7.1 shows the oat and broad bean biomass yield (kg ha-1) per block. The comparison of the two yield blocks shows minimal variation in the A-ES-MIN-FITO and H-ES-MIN treatments. The homogeneous treatments were A-ES, AS-ES-MIN, A-T, H-ES-MIN-FITO, H-ES-MIN, H-T, which increases the reliability of the results obtained.

**Figure 7.1** Dry biomass yield of forage oats per block




The most heterogeneous treatment was A-ES-MIN-FITO and is reported with the highest cost of production (Figure 7.2). In the oat crop, A-ES reported the highest yield and net gain with a cost of production $ 2,424 less than A-ES-MIN-FITO. The A-ES-MIN treatment was 20.8% less in yield and 31.9% less in profit compared to A-ES.

**Figure 7.2** Production costs and net profit per treatment




In the broad bean crop, the treatment with the highest economic investment was H-ES-MIN-FITO, being the treatment with the highest yield kg ha-1 due to the high synthesis of the hormones generated in the plant, developing high growth and cell division and prolonging an appropriate plant growth (Ligero and Lluch, 1986). Of the crops evaluated, the greatest investment was reflected in the A-ES-MIN and H-ES-MIN-FITO treatments. It should be noted that the minerals used were for the purpose of neutralizing the pH of the study area.

### 7.3 Conclusions

For higher forage yields in oats, fertilization of previously composted manure (A-ES) is suggested, which is economically feasible, in addition to mitigating the use of synthetic fertilisers and promoting the recycling of organic residues. It is important to note that the broad bean crop is adaptable to highly alkaline soils, so it will be more feasible and profitable for the farmer to cover his food demands with this legume. The results make it possible to meet the demands of family production and growth with equity and sustainable development. growth with equity and sustainable development, based on the study area.

### 7.4 References

ANÓNIMO. 2019. El Cultivo de Haba en Bolivia. Ministerio de Asuntos Campesinos y Agropecuarios. La Paz, Bolivia. 34 p.

ARIAS, A., CRUZ, J., PANTOJA, C., CONTRERAS, J. & LOPEZ, M. 2021. Rendimiento y calidad de Avena sativa asociada con Vicia sativa en la región puna del Perú. *Revista de Investigaciones Veterinarias del Perú,* 32. http://dx.doi.org/10.15381/rivep.v32i5.21339

CAMPUZANO, L. F., RINCÓN, E. C., SIERRA, J. C., CUESTA, D. T., SIERRA, D. F. N. & LOPEZ, P. A. P. 2020. Altoandina: nueva variedad de avena forrajera para la zona Andina en Colombia. Agronomía Mesoamericana, 31, 581-595. 9http://www.revistas.ucr.ac.cr/index.php/agromeso

DÍAZ R., R.; ESCALANTE E., A. 2019. Faba beans (*Vicia faba* L.) in Mexico. Grain Legumes51:3233. http://www.ias.csic.es/grainlegumesmagazine/Grain_Legumes_issue_51.pdf

ESPINOZA-MONTES, F., NUÑEZ-ROJAS, W., ORTIZ-GUIZADO, I. & CHOQUE-QUISPE, D. 2018. Producción de forraje y competencia interespecífica del cultivo asociado de avena (Avena sativa) con vicia (Vicia sativa) en condiciones de secano y gran altitud. *Revista de Investigaciones Veterinarias del Perú,* 29, 1237-1248. http://dx.doi.org/10.15381/rivep.v29i4.15202

FIGUEROA ARTEAGA, F. A. & MORALES TAMAYO, E. 2023. Potencial de manejo de arvenses de un cultivo de cobertura de avena (*Avena sativa L.*) a diferentes densidades de siembra. https://repositorio.ucaldas.edu.co/bitstream/handle/ucaldas/19545/Avena%2025Septiembre2022.pdf?sequence=1

*Ligero, F. and C. Lluch (1986). "Las fitohormonas en la simbiosis Rhizobiumleguminosa." Ars Pharmaceutica (Internet) 27(1): 107-110.*

MORALES, R. E.; DE LA O ÁVILA, H.; MORALES, R. A.; DE LA CRUZ, V. M. 2002. Evaluación de cinco genotipos de haba (*Vicia faba* L) con seis niveles de fósforo en Tecámac, México. *Ciencia Ergo Sum* 9(2): 184–189. http://redalyc.uaemex.mx/pdf/104/10402408.pdf

ROJAS, C. A. L. & VEGA, S. 1996. Evaluación del efecto de diferentes niveles de una enmienda orgánica en el rendimiento del Algodón (*Gossypium hirsutum L.*) var. reba P-279 y en algunas propiedades químicas de un suelo desgastado del departamento central del Paraguay. *Investigación Agraria,* 1, 27-34. https://www.agr.una.py/revista/index.php/ria/article/view/164

SIAP, S. D. I. A. Y. P. 2023. Avance de Siembras y Cosechas. Servicio de Información Agroalimentaria y Pesquera. https://nube.siap.gob.mx/avance_agricola/

VERHULST, N., SAYRE, K. & GOVAERTS, B. 2012. Manual de determinación de rendimiento. *México, Ciudad de México, SAGARPA, Centro Internacional de Mejoramiento de Maíz y Trigo,* 27-34. https://idp.cimmyt.org/publicacion/manual-del-determinacion-de-rendimiento/

# Chapter 8 Technological options for establishing pastures and increasing yield and nutrient value forage

# Capítulo 8 Opciones tecnológicas para establecer praderas e incrementar el rendimiento y valor nutritivo del forraje

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**Abstract**

In ruminant production systems, forage grasses are the main source of feed, as they are a relatively economical low-cost feed. However, to optimize forage production, it is suggested that pastures be established with the genotypes that best adapt to the conditions present in the production units (soil, precipitation, temperature, etc.) and consider the management that should be given to the crop during establishment (fertilization, weed and pest control, etc.). Once a pasture has been established, the dynamics of forage production during the year must be known, to plan the actions that must be carried out for when there is no availability. Forage grasses are classified as a food of low nutritional value due to their high structural carbohydrate content and low protein and digestibility values; However, in many cases, it is because they are not used at the most appropriate time, where the highest yield and nutritional value are obtained; This is achieved by harvesting or grazing before there are losses due to leaf senescence. On the other hand, during the dry season, fodder is not available, so it is suggested that it be conserved through silage.

**Biofertilizer, Forage production, Silage, Crude protein, Digestibility**

**Resumen**

En los sistemas de producción de rumiantes, las gramíneas forrajeras son la fuente principal de alimentación, por ser un alimento de bajo relativamente económico. Sin embargo, para optimizar la producción de forraje, se sugiere que se establezcan praderas con los genotipos que más se adapten a las condiciones presentes en las unidades de producción (suelo, precipitación, temperatura, etc.) y considerar el manejo que se le debe dar al cultivo durante el establecimiento (fertilización, control de malezas y plagas, etc.). Una vez que se tiene establecida una pradera, se debe conocer la dinámica de le producción de forraje durante el año, esto para planear las acciones que se deberán llevar a cabo para cuando no haya disponibilidad. Las gramíneas forrajeras son catalogadas como un alimento de bajo valor nutricional por sus altos contenidos de carbohidratos estructurales y bajos valores de proteína y digestibilidad; sin embargo, en muchas de los casos, se debe que no son aprovechadas en el momento más adecuado, donde se obtiene el mayor rendimiento y valor nutritivo; lo cual se logra al cosechar o pastorear antes de que existan pérdidas por senescencia foliar. Por otra parte, durante la época seca, no hay disponibilidad de forraje, por lo que se sugiere la conservación de éste mediante el ensilado.

**Biofertilizante, Producción de forraje, Ensilaje, Proteína cruda, Digestibilidad**

## 8 Introduction

It is estimated that by the year 2100 the world population will increase between 32 and 71%, which would represent between 9.5 and 12.3 billion people (Gerland *et al*., 2014). It is expected that by 2050, global demand for livestock products will double, in particular due to the improvement in the living conditions of the population (Rojas-Downing *et al*., 2017). To feed this population, beef will need to increase from 60 to 130 million tons and 70% of this production (49 million tons) is expected to come from tropical and subtropical regions of the world (Cooke *et al*., 2020). In Mexico, livestock farming is one of the main productive activities in rural areas, with cattle, pigs, goats, sheep, and poultry being used to produce meat, milk or eggs (Bautista-Martínez *et al*., 2019). Of these species, the most important are ruminants, especially cattle, and their production is developed under two systems: intensive and extensive, the latter being the one that predominates at the national level. Extensive systems have grasslands and cutting and/or grazing meadows as their main food source, since forage from these sites is considered a low-cost food and, therefore, production costs are lower (Albarrán-Portillo *et al*., 2015).

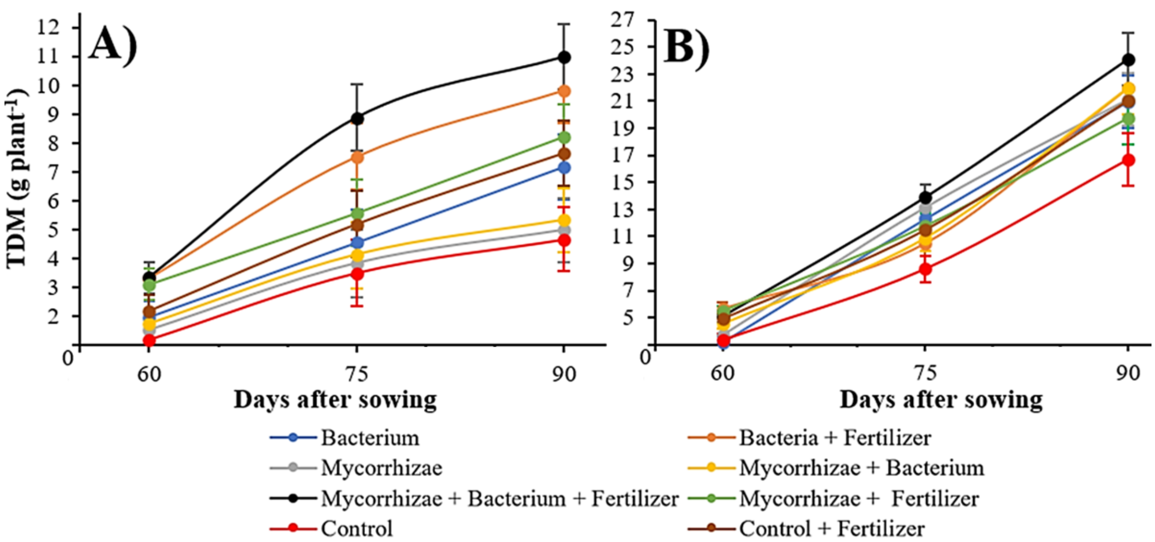
### 8.1 Establishment of grasslands

For a new meadow to be productive, it is necessary to ensure adequate establishment in the shortest possible time, and special attention must be paid to this stage, since it is when the root and foliar system is generated and expanded, which will determine the capacity for the use of environmental resources (water, nutrients, etc.).  light, etc.) and competition with weeds (Garay *et al*., 2012).

In this sense, nutrient availability plays an important role in plant growth and development, and some tropical grasses such as those of the genera *Pennisetum, Megathyrsus, Cynodon* and *Urochloa*, require around 60 and 30 kg $ha^{-1}$ of nitrogen and phosphorus, respectively, during establishment. However, many of the soils have low fertility, which makes fertilization necessary, which is usually chemical (Enríquez *et al.*, 2011) and currently the price of chemical fertilizers has increased by up to 60 %, which means that they are no longer used to reduce production costs.

Faced with this situation, mycorrhizae and nitrogen-fixing bacteria have been proposed as an alternative, as they have been shown to significantly increase the growth and development of *Urochloa brizantha* grass, which reduces the use of chemical fertilizers (Moreira *et al*., 2020). Microbial inoculants, also called biofertilizers, have received increasing attention in some countries, gaining prominence and market scale in the agricultural sector (Sánches *et al*., 2019). In this sense, arbuscular mycorrhizal fungi (AMF) are microorganisms that have the ability to improve plant yields, change the plant-water ratio and increase productivity, even in drought conditions. Recent studies have shown that AMF increased water use efficiency by improving stomatal conductance (Augé *et al.*, 2015*)* and increasing the activity of antioxidant enzymes to reduce peroxidative damage (Duc *et al.*, 2018). In the case of plant growth-promoting rhizobacteria, these microorganisms are able to create symbiosis with plants and generate benefits such as at least partially meeting the plant's nitrogen demands, as well as initiating a variety of processes that include the production of phytohormones, siderophores, phosphate solubilization, induction of systemic resistance intrinsic to abiotic and biotic stress, among others (Fukami *et al*., 2018). In this sense, a study was carried out and it was found that the seed of Mavuno grass inoculated with *Azospirillum brasilense*, up to 90 days after sowing, significantly increased the total dry matter yield and was similar to fertilization with 60-40-40 NPK; therefore, during this time, chemical fertilization could be dispensed with (Sánchez *et al.*, 2022; Figure 8).

**Figure 8** Total dry matter (TDM) yield of Mavuno grass (*Urochloa* hybrid), fertilized and inoculated with mycorrhizae *(Glomus* spp.) and bacteria (*Azospirillum brasilense*), in two humidity regimes: 50 (A) and 100 % (B) of field capacity. *Fertilizer (60-40-40 NPK). The overlapping bars indicate that there is no statistically significant difference (Tukey; α=0.05)

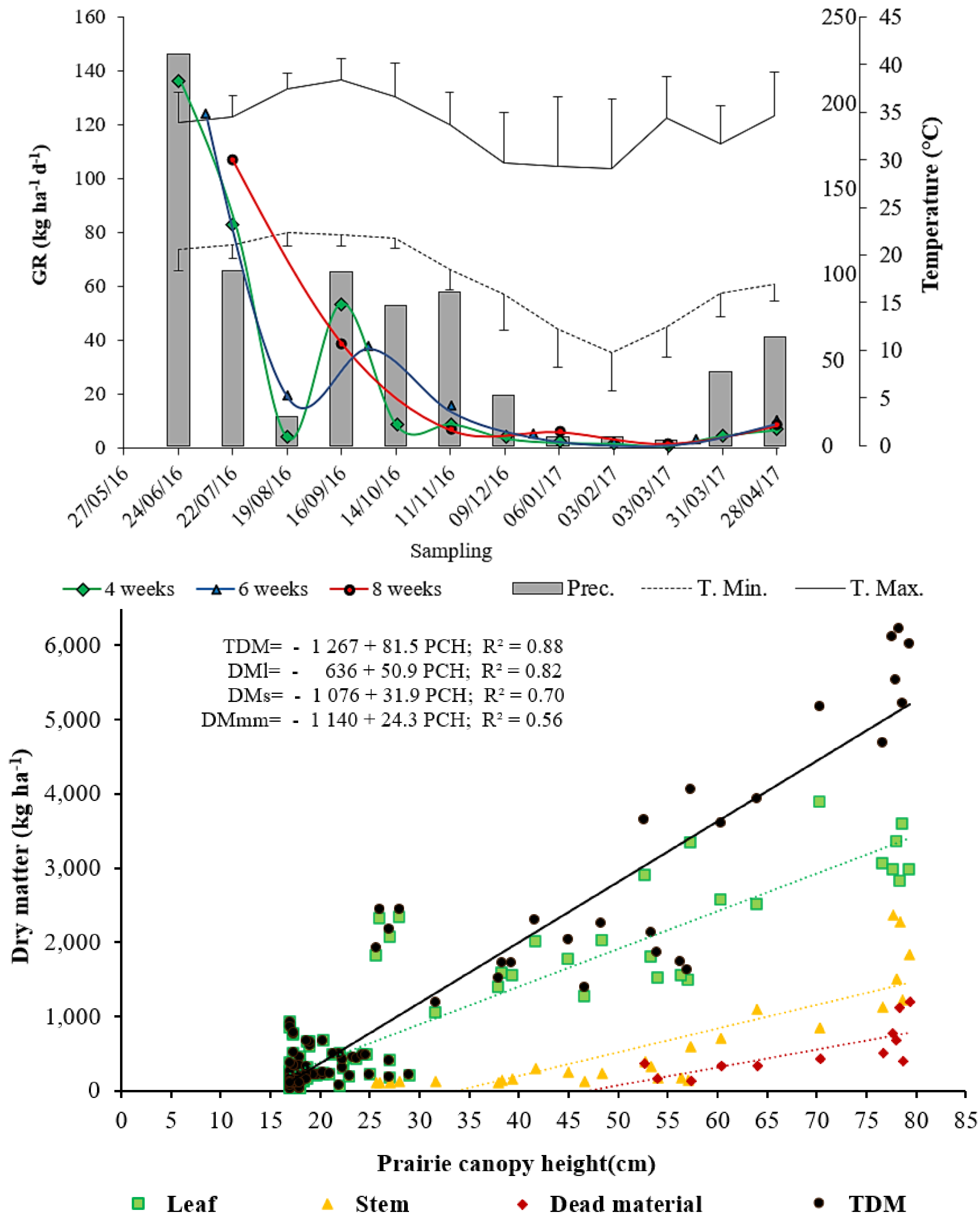



## 8.2 Production and nutritive value of forage

Regarding forage yield, it should be taken into account that it is influenced by genotype and fluctuations in temperature and precipitation during the year (Martínez-López *et al.*, 2014). It should be considered that the grassland is a dynamic ecosystem and as such, it needs strategic management to maintain forage production and persistence (Cruz *et al.*, 2011). Within management, practices such as fertilization and the intensity and age of regrowth, at which fodder is grazed or harvested, stand out (Cruz-Hernández *et al.*, 2017). The age of regrowth has a positive correlation with forage yield, but a negative correlation with forage quality (Garay *et al.*, 2017). This is a consequence of the maturity of the plant, which causes changes in the relationship to the morphological components; that is, there is a reduction in the proportion of leaves and an increase in stems and dead material (Garay *et al.*, 2017).

It has been mentioned that the best time to harvest a forage is before foliar senescence, to avoid losses in both yield and quality (Silva *et al.*, 2016). The height of the meadow is a practical way of knowing when the best time is to take advantage of the forage resource, as it influences the leaf area index which in turn will determine the leaf senescence of the lower stratum (Silva *et al.*, 2016). In this regard, a study was carried out (Garay *et al.*, 2019) and it was concluded that in Buffel grass forage production, environmental factors and regrowth age had a significant effect on the growth rate, which was reflected in the dynamics of forage yield and accumulation and the structural behavior of dry matter in *Pennisetum ciliare* cv. H-17 (Figure 8.1).

**Figure 8.1** Growth Rate (GR) and relationship between prairie canopy height (PCH) and total dry matter yield (TDM) and morphological components [leaf (DMl), stem (DMs) and dead material (DMmm)] in *Pennisetum ciliare* cv. H-17, harvested at three regrowth ages (weeks) and distribution of the accumulated monthly precipitation (Prec.) and average monthly maximum (T. Max.) and minimum (T. Min.) temperature recorded during the evaluation



To obtain the highest forage yield and avoid losses due to foliar senescence in *Pennisetum ciliare* cv. H-17, should be harvested when the height of the meadow reaches between 40 and 50 cm (Figure 2). Likewise, when tropical forages are harvested at an early age, 4 or 6 weeks of regrowth, they can be high in crude protein and digestibility. *Urochloa* hybrids maintain forage quality even at 8 weeks after regrowth, while *Pennisetum ciliare* cv. H-17 only matched Mulato II in crude protein and digestibility at 4 weeks after regrowth. The Cobra hybrid had the highest forage yield during the season of low rainfall (Garay *et al*., 2020; Table 8).

**Table 8** Total dry matter (TDM), crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) of *Pennisetum ciliare* cv. H-17 and *Urochloa* hybrids (Cayman, Cobra and Mulato II) at different regrowth age (RA; weeks), during the period of maximum and minimum precipitation

| RA | Cultivate | Maximum precipitation season | | | | | | | Minimum precipitation season | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TDM (t ha$^{-1}$) | | CP (%) | | IVDMD (%) | | | TDM (t ha$^{-1}$) | | CP (%) | | IVDMD (%) | |
| 4 | Cayman | 3.76 | a | 14.1 | a | 74.9 | a | | 0.16 | ab | 12.4 | ab | 72.0 | a |
| | Cobra | 3.36 | a | 12.5 | b | 72.8 | b | | 0.21 | a | 11.6 | bc | 71.1 | ab |
| | Mulato II | 3.63 | a | 11.3 | bc | 69.3 | c | | 0.18 | ab | 12.7 | ab | 70.1 | b |
| | H-17 | 3.28 | a | 10.4 | c | 67.3 | c | | 0.10 | b | 11.5 | c | 68.6 | c |
| | Average | 3.51 | C | 12.1 | A | 71.1 | A | | 0.16 | C | 12.0 | A | 70.5 | A |
| 6 | Cayman | 5.14 | a | 11.6 | a | 70.2 | a | | 0.20 | b | 12.1 | a | 71.6 | a |
| | Cobra | 4.79 | a | 9.9 | b | 70.1 | a | | 0.25 | a | 11.4 | ab | 70.5 | ab |
| | Mulato II | 5.17 | a | 9.9 | b | 67.7 | b | | 0.23 | ab | 11.6 | a | 70.2 | b |
| | H-17 | 4.85 | a | 7.6 | c | 60.6 | c | | 0.20 | b | 10.5 | b | 67.5 | c |
| | Average | 4.99 | B | 9.7 | B | 67.1 | B | | 0.22 | B | 11.4 | B | 69.9 | A |
| 8 | Cayman | 6.04 | a | 10.2 | a | 67.3 | a | | 0.36 | bc | 9.5 | a | 66.4 | a |
| | Cobra | 5.87 | ab | 9.7 | ab | 67.1 | a | | 0.40 | a | 9.0 | b | 66.0 | a |
| | Mulato II | 5.78 | b | 9.2 | b | 66.3 | a | | 0.38 | ab | 9.5 | a | 65.1 | a |
| | H-17 | 5.24 | c | 7.4 | c | 56.3 | b | | 0.33 | c | 8.5 | c | 62.4 | b |
| | Average | 5.73 | A | 9.1 | C | 64.2 | C | | 0.37 | A | 9.1 | C | 65.0 | B |

Different literals between cultivars (a, b, c) and regrowth ages (A, B, C) within the season indicate statistically significant differences (Tukey; α=0.05).

### 8.3 Forage conservation

On the other hand, to minimize the effects of poor rainfall and the consequent lack of feed during the dry season, an alternative that has been used is silage, in particular, corn (Daniel *et al*., 2019). As a feed source for ruminants, corn silage has the ability to provide forage with high energy content, starch, soluble carbohydrates, and fiber (Zhao *et al*., 2021) and is safe to use in animal feed at any stage of growth. Although corn silage is an excellent source of energy (Erdal *et al*., *2016), it is low in protein (*Zhao *et al*., 2021). For this reason, it is necessary to add additional supplements to balance ruminant diets, as protein is an essential nutrient for the development and reproduction of animals.

Due to the above, the use of legumes has been proposed as an option to increase the protein content in animal diets. This is particularly important for livestock production in tropical and subtropical climates when forages are low in protein (Wassie *et al*., 2019). In this sense, soybeans are a legume with a high protein concentration, so they can contribute to improving the nutritional quality of corn silage (Zhao *et al*., 2021). The positive effects of the combination of corn and soybean forage on silage quality have already been documented (Zhao *et al*., 2021). However, there is limited information available on the nutritional quality of these combinations in tropical and subtropical climates. Likewise, in the search for alternatives for the conservation of legume forage, some additives such as molasses have been tested (López-Herrera *et al*., 2022), however, so far there are few publications related to its application in soybean forage silage. It has been reported that, for the conservation of corn and soybean forage, the treatment that had the highest nutritional quality without seriously compromising the silage process was the combination with 60% corn and 40% soybeans (Figure 3; Garay-Martínez *et al*., 2021); whereas, for proper preservation of soybean forage through silage, 66% molasses should be applied, either in layers of 10 or 20 cm; and this ensures the proper fermentation process, having a pH in the silage that ranges between 3.8 and 4.0 (Figure 8.3; Garay-Martínez *et al*., 2023).

**Figure 8.2** Chemical characteristics of corn and soybean forage silage and their different proportions. S100: 100 % soybean; M100: 100 % corn; S80M20: soybean 80 % + corn 20 %; S60M40: 60 % soybean + 40 % corn; S40M60: soybean 40 % + corn 60%; S20M80: Soybean 20 % + Corn 80 %. Different letters, indicate statistically significant difference (Tukey; α=0.05)

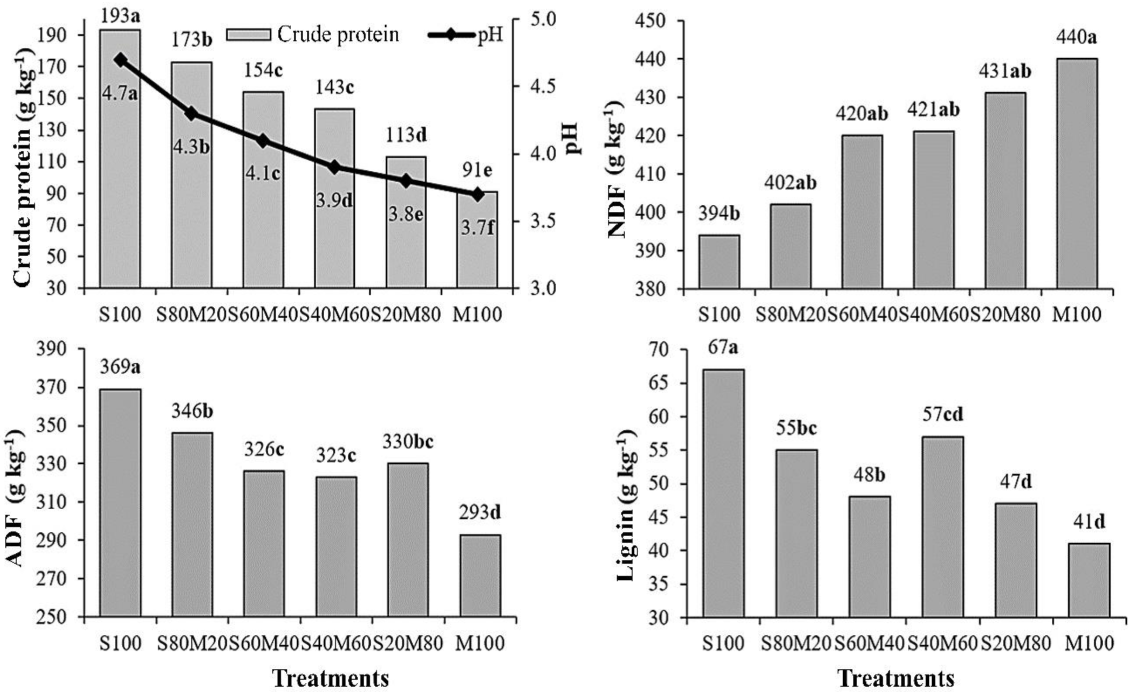
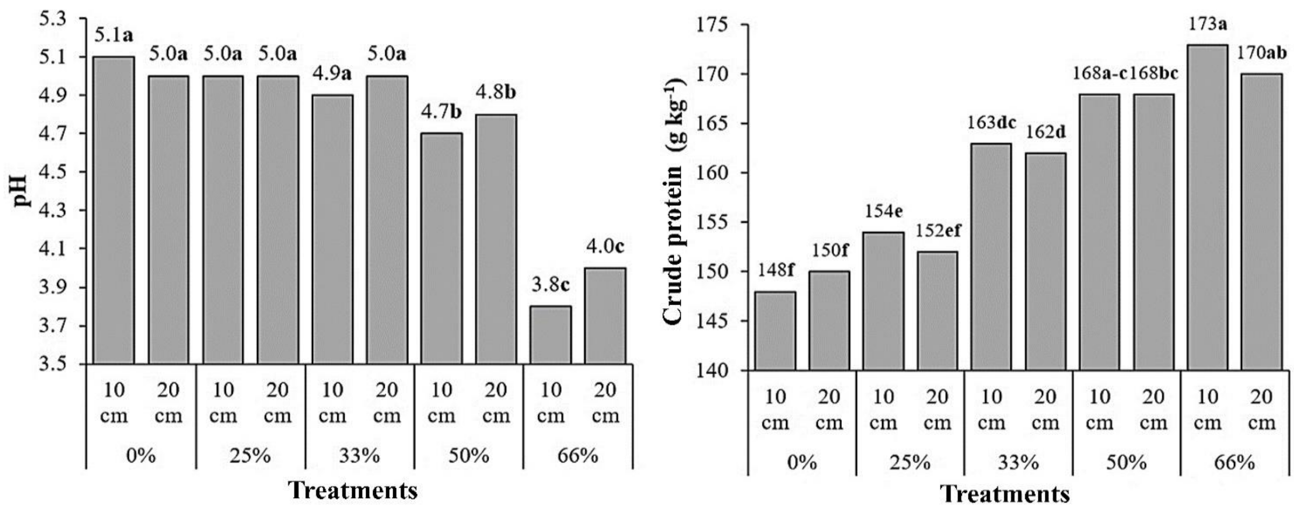



**Figure 8.3** Crude protein and pH of soybean forage silage with different molasses levels (0, 25, 33, 50 and 66 %) and application in forage layers (10 and 20 cm). Different letters, indicate statistically significant difference (Tukey; α=0.05)




## 8.4 Conclusions

Mycorrhizae and/or nitrogen-fixing bacteria can be used to establish grasslands, which can help reduce the costs involved in purchasing and applying chemical fertilizers; in addition to reducing environmental pollution. While to increase the yield and nutritional value of the forage there are several options, among which the choice of the cultivar or genotype, the optimal harvest date and the inclusion of legumes stand out.

**8.5 References**

Albarrán-Portillo, B., Rebollar-Rebollar, S., García-Martínez, A., Rojo-Rubio, R., Avilés-Nova, F., & Arriaga-Jordán, C. M. (2015). Socioeconomic and productive characterization of dual-purpose farms oriented to milk production in a subtropical region of Mexico. *Tropical Animal Health and Production*, 47: 519-523. https://doi.org/10.1007/s11250-014-0753-8

Augé, R. M., Toler, H. D. and Saxton, A. M. (2015). Arbuscular mycorrhizal symbiosis alters stomatal conductance of host plants more under drought than under amply watered conditions: a meta-analysis. *Mycorrhiza*, 25:13–24. https://doi.org/10.1007/s00572-014-0585-4

Bautista-Martínez, Y., Haro, J. G. H., García, J. E., Castañeda, F. E. M., Vaquera-Huerta, H., Morales, A., & Guzmán, G. A. (2019). Caracterización económico-productiva del sistema bovino doble propósito en tres regiones tropicales de México. *ITEA, Información Técnica Económica Agraria: revista de la Asociación Interprofesional para el Desarrollo Agrario (AIDA)*, 115(2), 134-148.

Cooke, R. F., Daigle, C. L., Moriel, P., Smith, S. B., Tedeschi, L. O., y Vendramini, J. M. B. (2020). Cattle adapted to tropical and subtropical environments: social, nutritional, and carcass quality considerations. *Journal of Animal Science, 98*(2): 1-20. https://doi.org/10.1093/jas/skaa014

Cruz, A., Hernández, A., Enríquez, J. Gómez, A., Ortega, E. y Maldonado, N. (2011). Producción de forraje y composición morfológica del pasto Mulato (*Brachiaria híbrido* 36061) sometido a diferentes regímenes de pastoreo. Revista Mexicana de Ciencias Pecuarias 2:429-443.

Cruz-Hernández, A., Hernández-Garay, A., Aranda-Ibañez, E., Chay-Canul, A.J., Márquez-Quiroz, C., Rojas-García, A.R., and Gómez-Vázquez, A. (2017). Nutritive value of Mulato Grass under different grazing strategies. Ecosistemas y Recursos Agropecuarios 4(10):65-72.

Daniel, J. L. P., Bernardes, T. F., Jobim, C. C., Schmidt, P., y Nussio, L. G. (2019). Production and utilization of silages in tropical areas with focus on Brazil. *Grass and Forage Science, 74*(2), 188-200. https://doi.org/10.1111/gfs.12417

Duc, N. H., Csintalan, Z. and Posta, K. (2018). Arbuscular mycorrhizal fungi mitigate negative effects of combined drought and heat stress on tomato plants. *Plant Physiology and Biochemistry,* 132, 297–307. https://doi.org/10.1016/j.plaphy.2018.09.011

Enríquez, J. F., Meléndez, F., Bolaños, E. D., y Esqueda, V. A. (2011). Producción y manejo de forrajes tropicales. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, México. 405 p.

Erdal, S., Pamukcu, M., Curek, M., Kocaturk, M., y Dogu, O. Y. (2016). Silage yield and quality of row intercropped maize and soybean in a crop rotation following winter wheat. *Archives of Agronomy and Soil Science 62*, 1487-1495. https://doi.org/10.1080/03650340.2016.1153801

Fukami, J., De La Osa C., Ollero F. J., Megías M. and Hungria M. (2018b). Co-inoculation of maize with *Azospirillum brasilense* and *Rhizobium tropici* as a strategy to mitigate salinity stress. *Functional Plant Biology*, 45(3):328-339. https://doi.org/10.1071/FP17167

Garay J.R., Estrada B., Bautista Y., Bernal Á., Mendoza S.I., Martínez J.C., Sosa E., Joaquín S. (2020). Forage yield and quality of buffel ‘H-17’ and Urochloa hybrids at different regrowth ages under semi-arid conditions. Grassland Science, 66(4): 277-284. https://doi.org/10.1111/grs.12278

Garay J.R., Joaquín S., Estrada E., Martínez J.C., Limas A.G., Hernández J., Rojas A.F. (2019). Producción y cambios morfológicos de Pennisetum ciliare cv. H-17 en función de la edad de rebrote y altura de pradera. *Acta Universitaria* 29: 1-13. https://doi.org/10.15174/au.2019.2306

Garay, J. R., E.G. Cienfuegos, J. A. Espinosa, P. Zárate y M. A. Ibarra. (2012). Análisis de crecimiento inicial de cinco genotipos de brachiaria en trópico húmedo. *TsaFiqui-Revista de Investigación Científica* 3:83-93. https://doi.org/10.29019/tsafiqui.v0i3.223

Garay, J. R., S. Joaquín, P. Zárate, M. A. Ibarra, J. C. Martínez, R. P. González, and E. G. Cienfuegos. (2017). Dry matter accumulation and crude protein concentration in *Brachiaria* spp. cultivars in the humid tropics of Ecuador. *Tropical Grasslands-Forrajes Tropicales* 5(2):66-76.

Garay-Martínez J.R., Granados-Rivera L.D., Lucio-Ruiz F., Godina-Rodríguez J.E, Maldonado-Jáquez J.A., Joaquín-Cancino S. (2021). Mezcla de forraje de maíz y soya para incrementar el valor proteico del ensilado. En: Cigarroa F.A., Hernández M.I., Esponda W. (Eds.). III Congreso Internacional en Ciencias Agronómicas y Veterinarias. CICAV-2021. Chiapas, México. pp: 103-106.

Garay-Martínez J.R., Granados-Rivera L.D., Maldonado-Moreno N., Hernández E.A., Olivares-Nochebuena M. (2023). Forraje de soya adicionado con melaza para su conservación mediante el ensilaje. En: Preciado P., Gallegos M.A., Fotis M., Gutiérrez U.N., Ruiz F.J., Puentes J. (Eds.). XXXV Semana Internacional de Agronomía. Durango, México. pp: 1507-1513.

Gerland, P., Raftery A. E., Ševčíková, H., Li, N., Gu, D., Spoorenberg, T., Alkema, L., Fosdick, B. K., Chunn, J., Lalic, N., Bay, G., Buettner, T., Heilig, G.K., y Wilmoth, J. (2014). World population stabilization unlikely this century. *Science*, *346*(6206), 234-237. https://doi.org/10.1126/science.1257469

López-Herrera, M., Castillo-Umaña, M., Alpízar-Naranjo, A., y Arias-Gamboa. M. (2022). Composición bromatológica de ensilados de leguminosas con diferentes fuentes de carbohidratos. *Nutrición Animal Tropical 16*(2),115-133. https://doi.org/10.15517/nat.v16i2.52922

Martínez-López, J. R., Gutiérrez-Ornelas, E., Barrera-Silva, M. A., and Retes-López, R. (2014). Simulación estocástica para praderas de pasto buffel (*Cenchrus ciliaris* L.) en Marin, N. L., México. *Tropical and Subtropical Agroecosystems*, 17:87-104.

Moreira, B. R. A., Viana, R. S., Favato, V. L., Figueiredo, P. A. M., Lisboa, L. A. M., Miasaki, C. T., *et al*. (2020). *Azospirillum brasilense* can impressively improve growth and development of *Urochloa brizantha* under irrigation. *Agriculture* 10(6):220. https://doi.org/10.3390/agriculture10060220

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, y T., Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, *16*, 145-163. https://doi.org/10.1016/j.crm.2017.02.001

Sánches S., M., Nogueira, M. A. and Hungria, M. (2019). Microbial inoculants: reviewing the past, discussing the present and previewing an outstanding future for the use of beneficial bacteria in agriculture. *AMB Expr*, 9: 205. https://doi.org/10.1186/s13568-019-0932-0

Sánchez E., Garay J.R., Alvarado E.R., Felipe M., Patishtan J., Torres R.I. (2022). Rendimiento de materia seca de pasto Mavuno (*Urochloa* híbrido) inoculado con *Glomus* spp., y *Azospirillum brasilense.* En: Anaya A.M., García C., Alvarado L.Y., Arechaveleta M.E., Reyes M. (Comp.). LVII Reunión Nacional de Investigación Pecuaria. INIFAP. Villahermosa, Tabasco, México. pp: 230-232.

Silva, V. J., Pedreira, C. G. S., Sollenberger, L. E., Silva, L. S., Yasuoka, J. I., and Almeida, I. C. L. (2016). Canopy height and nitrogen affect herbage accumulation, nutritive value, and grazing efficiency of 'Mulato II' brachiariagrass. *Crop Science*, 56(4):2054-206.

Wassie, S. H., Ali, A. I. M., Korir, D., Butterbach-Bahl, K., Goopy, J., Merbold, L., Schlecht, E., and Dickhoefer, U. (2019). Effects of feed intake level on efficiency of microbial protein synthesis and nitrogen balance in Boran steers consuming tropical poor-quality forage. *Archives of Animal Nutrition, 73*(2), 140-157. https://doi.org/10.1080/1745039x.2019.1572343

Zhao, C., Wang, L., Ma, G., Jiang, X., Yang, J., Lv, J., y Zhang, Y. (2021). Cellulase interacts with lactic acid bacteria to affect fermentation quality, microbial community, and ruminal degradability in mixed silage of soybean residue and corn stover. *Animals*, *11*(2), 334. https://doi.org/10.3390/ani11020334

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# Chapter 9 Pig immunocastration: advances in the sustainability of pig production

# Capítulo 9 Inmunocastración de cerdos: avances en la sustentabilidad de la producción porcina

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**Abstract**

Immunocastration, a method that uses the animal's immune system to generate antibodies against the GnRH hormone, which results in the reduction of sex hormones and, consequently, of compounds responsible for boar taint in meat. Immunocastration improves animal welfare, reduces production costs and has a positive impact on environmental sustainability. Immunocastration is an alternative to surgical castration, avoiding the pain and stress associated with this procedure. In addition, it improves the quality of meat and economic benefits for producers. But there are some challenges, such as possible side effects and variability in vaccine effectiveness between individuals. The reluctance of some markets or consumers towards meat from immunocastrated animals is also highlighted. In conclusion, immunocastration is highlighted as a promising option in animal production, with significant benefits, but the importance of addressing challenges and limitations to optimize its effectiveness and market acceptance is emphasized.

**Pigs, Escatol, Testosterone, Castration**

**Resumen**

La inmunocastración, un método que utiliza el sistema inmunológico del animal para generar anticuerpos contra la hormona GnRH, lo que tiene como resultado la reducción de hormonas sexuales y, consecuentemente, de compuestos responsables del olor sexual en la carne. La inmunocastración mejora el bienestar animal, reduce costos de producción y tiene un impacto positivo en la sostenibilidad ambiental. La inmunocastración es una alternativa a la castración quirúrgica, evitando el dolor y el estrés asociados con este procedimiento. Sin embargo, mejora la calidad de la carne y los beneficios económicos para los productores. Pero hay algunos desafíos, como posibles efectos secundarios y variabilidad en la eficacia de la vacuna entre individuos. También se destaca la reticencia de algunos mercados o consumidores frente a la carne de animales inmunocastrados. En conclusión, se resalta la inmunocastración como una opción prometedora en la producción animal, con beneficios significativos, pero se enfatiza la importancia de abordar desafíos y limitaciones para optimizar su efectividad y aceptación en el mercado.

**Porcinos, Escatol, Testosterona, Castración**

## 9 Introduction

Pork production is an important economic activity in many countries around the world (Squires et al., 2020) and its sustainability is an increasingly relevant issue. Sustainability refers to the ability to meet current needs without compromising the livelihood of future generations. In some countries, citizens are concerned about the impact of intensive farm animal production conditions on animal welfare and the environment (Kress et al., 2019). Immunocastration is a technique that has been proposed as an alternative to surgical castration of male pigs, with the aim of improving animal welfare and reducing the environmental impact of pig production.

Surgical castration of male pigs is a common practice in pig production, as it reduces taint in the meat and prevents problems with aggressive behavior and mounting (Čandek-Potokar et al., 2017). However, this activity also has some disadvantages, such as the pain and stress it causes in animals, as well as the risk of infections and other health problems (Yun et al., 2019). Surgical castration can have a negative impact on the sustainability of pig production, as it increases the environmental footprint and can affect the quality of the meat (Aráoz de Lamadrid, 2016).

Immunocastration consists of the administration of a vaccine that decreases androgen production in male pigs; this has an effect equivalent to surgical castration (Han et al., 2017). This practice has been the subject of research in recent years, and it has been shown that it can improve animal welfare and reduce the environmental impact of pork production (De Moraes et al., 2013). In this work, immunocastration and its relationship with the sustainability of pig production will be discussed. The main aspects of immunocastration will be presented, as well as the benefits and disadvantages of this technique in terms of animal welfare, meat quality and environmental footprint.

## 9.1 Materials and methods

This study was based on an in-depth review of the scientific and technical literature related to the topic of immunocastration of pigs and its impact on the sustainability of pig production. Literature searches were conducted in academic and scientific databases, such as PubMed, Scopus, Web of Science, and Google Scholar, using key terms such as “immunocastration,” “pigs,” “sustainability,” and “swine production.” Relevant studies were selected by reviewing the titles and abstracts in the initial searches. Studies were selected that provide substantial information on advances in pig immunocastration and its relationship to sustainability.

A synthesis of the information collected from the selected studies was carried out. Relevant findings related to pig immunocastration and its effects were organized and categorized in terms of sustainability, including aspects such as animal welfare, production efficiency and environmental impact.

## 9.2 Results

### *9.2.1 Immunocastration*

Immunocastration involves activating the animal's immune system to generate specific antibodies directed against the hormone GnRH (gonadotropin-releasing hormone) (Zamaratskaia & Rasmussen, 2015). These antibodies have the ability to interfere with the normal function of GnRH, decreasing the concentrations of the hormones LH and FSH in the blood and suppressing the development and function of the testicles. As a result, the levels of androstenone and skatole in the animal's fat are reduced, which in turn reduces the incidence of boar taint in meat carcasses (Lin-Schilstra & Ingenbleek, 2022) (Figure 1).

Immunocastration takes advantage of the animal's natural immune system to achieve the effects of castration (Mancini et al., 2017). The vaccine contains an inactive version of the hormone GnRH, which is covalently linked to a carrier protein with immunogenic properties. Although this GnRH analog lacks hormonal activity, it contains the necessary characteristics to stimulate an efficient antibody response against GnRH, thereby blocking stimulation of the hypothalamic-pituitary-gonadal axis (Brunius et al., 2011). As a result, the production of gonadal sex hormones is hindered, causing regression of the reproductive organs and some associated metabolic changes. These changes ultimately translate into behavioral modifications, such as a decrease in aggression and an increase in appetite and food intake, as well as improvements in growth performance (Čandek-Potokar et al., 2017).

### *9.2.2 Benefits of immunocastration in animal production*

Immunocastration can help improve animal welfare by avoiding surgical castration, which can be painful and stressful for animals. According to FAO (2023), animal welfare is an important pillar in animal production, as it guarantees the safety and maximum performance of animals. Immunocastration can have economic benefits for producers, as it can improve meat quality and reduce production costs. According to Casanova Lugo (2018), silvopastoral systems emerge as a sustainable technological option for livestock production, and immunocastration can be a complementary technique to improve meat quality and reduce production costs.

Immunocastration can also contribute to the sustainability of animal production, as it reduces the environmental impact of production. According to Van den Broeke et al., (2022) immunocastration can reduce greenhouse gas emissions and water and feed consumption in animal production. The evaluation of the impact of immunocastration on animal production in terms of sustainability has been carried out through different indicators, among which is animal welfare. Immunocastration is a technique that avoids surgical castration, which can improve animal welfare. According to the Argentine Journal of Animal Production (2015), immunocastration can reduce pain and stress in animals, which contributes to improving their well-being (Heyrman et al., 2019).

The environmental impact of animal production can be reduced with the use of immunocastration, since it reduces the emission of greenhouse gases and the consumption of water and feed in pig farms. According to Basulto Baker, (2020), immunocastration can contribute to the sustainability of animal production, it can also improve the quality of meat, which can have economic benefits for producers. According to Casanova Lugo (2018), immunocastration can be a complementary technique to improve meat quality and reduce production costs.

### *9.2.3 Challenges and limitations of immunocastration*

Immunocastration also presents challenges and limitations. According to the Argentine Journal of Animal Production (2015), immunocastration can have side effects in animals, such as the formation of abscesses at the vaccination site. However, it may be more expensive than surgical castration in some cases, as the implementation of immunocastration entails additional costs, including the cost of vaccines and staff training, which may influence the profitability of pig production ( Rueff et al., 2019).

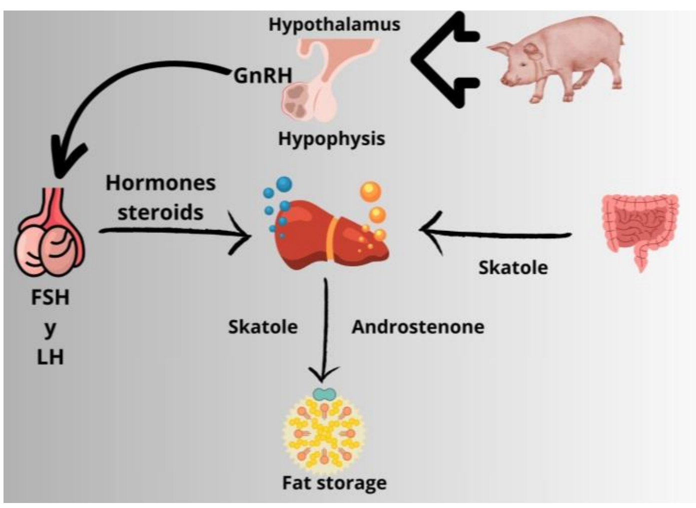
Another aspect that has limited the flourishing of immunocastration is that vaccine efficacy can be variable between individuals, meaning that some pigs may not develop a sufficient immune response to achieve effective castration because immunocastration is not a process. immediate; It takes time for the antibodies generated to completely block the action of GnRH. During this transition period, pigs may continue to exhibit undesirable behaviors and produce androstenone (Zamaratskaia & Rasmussen, 2015).

Finally, some markets or consumers may not accept meat from immunocastrated pigs due to concerns about the residual presence of antibodies or perceived changes in meat quality (Kallas et al., 2013).

## 9.3 Discussion and conclusions

Immunocastration is a good alternative to surgical castration in animal production; it can be used with the aim of improving the sustainability of production and reducing environmental impact. Immunocastration can also contribute to improving animal welfare and have economic benefits for producers. However, it is important to take into account the challenges and limitations of this technique and continue research to improve its effectiveness and reduce its side effects.

**Figure 9** There is an interconnection between the hypothalamic-pituitary-gonadal system, the synthesis of androstenone in the testes and the transformation of tryptophan into skatole in the intestine, as well as its processing in the liver. In boars, testicular steroid production, including androstenone, has the ability to hinder the elimination of skatole in the liver. Both androstenone and skatole accumulate in adipose tissue due to their affinity for fat. Figure modified from Čandek-Potokar et al., (2017)




## 9.4 Gratitude

To COMECyT for the professorship awarded to the author of this document under the COMECyT Researchers program (ESYCA2023-1957).

**9.5 References**

Aráoz de Lamadrid, J. G. (2016). Evaluación de la inmunocastración como herramienta para mejorar parámetros productivos en la producción porcina [en línea]. Trabajo Final de Ingeniería en Producción Agropecuaria. Facultad de Ciencias Agrarias. Universidad Católica Argentina. Disponible en: https://repositorio.uca.edu.ar/handle/123456789/352

Basulto Baker, R. (2020). La castración inmunológica de los cerdos machos: Estado actual. Revista de Producción Animal, 32(3), 40–56. http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S2224-79202020000300040&lng=es&nrm=iso&tlng=es

Brunius, C., Zamaratskaia, G., Andersson, K., Chen, G., Norrby, M., Madej, A., & Lundström, K. (2011). Early immunocastration of male pigs with Improvac® – Effect on boar taint, hormones and reproductive organs. Vaccine, 29(51), 9514–9520. https://doi.org/10.1016/j.vaccine.2011.10.014

Casanova Lugo, F. (2018). "Avances de la investigación sobre producción animal y seguridad alimentaria en México." Revista de Investigación Académica, 35, 1-10. https://www.researchgate.net/profile/Fernando-Casanova-Lugo/publication/325807244_Avances_de_la_investigacion_sobre_produccion_animal_y_seguridad_alimentaria_en_Mexico/links/5b578a9e0f7e9bc79a609bc8/Avances-de-la-investigacion-sobre-produccion-animal-y-seguridad-alimentaria-en-Mexico.pdf

Čandek-Potokar, M., Škrlep, M., Zamaratskaia, G., Čandek-Potokar, M., Škrlep, M., & Zamaratskaia, G. (2017). Immunocastration as Alternative to Surgical Castration in Pigs. En *Theriogenology*. IntechOpen. https://doi.org/10.5772/intechopen.68650

De Moraes, P. J. U., Allison, J., Robinson, J. A., Baldo, G. L., Boeri, F., & Borla, P. (2013). Life cycle assessment (lca) and environmental product declaration (epd) of an immunological product for boar taint control in male pigs. *Journal of Environmental Assessment Policy and Management*, *15*(01), 1350001. https://doi.org/10.1142/S1464333213500014
FAO. (2023). "Introducción." En Bienestar animal y producción animal. FAO.

Han, X., Zhou, Y., Zeng, Y., Sui, F., Liu, Y., Tan, Y., Cao, X., Du, X., Meng, F., & Zeng, X. (2017). Effects of active immunization against GnRH versus surgical castration on hypothalamic-pituitary function in boars. *Theriogenology*, *97*, 89–97. https://doi.org/10.1016/j.theriogenology.2017.04.038

Heyrman, E., Kowalski, E., Millet, S., Tuyttens, F. A. M., Ampe, B., Janssens, S., Buys, N., Wauters, J., Vanhaecke, L., & Aluwé, M. (2019). Monitoring of behavior, sex hormones and boar taint compounds during the vaccination program for immunocastration in three sire lines. *Research in Veterinary Science*, *124*, 293–302. https://doi.org/10.1016/j.rvsc.2019.04.010

Kallas, Z., Gil, J. M., Panella-Riera, N., Blanch, M., Font-i-Furnols, M., Chevillon, P., De Roest, K., Tacken, G., & Oliver, M. A. (2013). Effect of tasting and information on consumer opinion about pig castration. *Meat Science*, *95*(2), 242–249. https://doi.org/10.1016/j.meatsci.2013.05.011

Kress, K., Millet, S., Labussière, É., Weiler, U., & Stefanski, V. (2019). Sustainability of Pork Production with Immunocastration in Europe. *Sustainability*, *11*(12), Article 12. https://doi.org/10.3390/su11123335

Lin-Schilstra, L., & Ingenbleek, P. T. M. (2022). A Scenario Analysis for Implementing Immunocastration as a Single Solution for Piglet Castration. *Animals : an Open Access Journal from MDPI*, *12*(13), 1625. https://doi.org/10.3390/ani12131625

Mancini, M. C., Menozzi, D., & Arfini, F. (2017). Immunocastration: Economic implications for the pork supply chain and consumer perception. An assessment of existing research. Livestock Science, 203, 10–20. https://doi.org/10.1016/j.livsci.2017.06.012

Revista Argentina de Producción Animal. (2015). "Ganado patagónico: una alternativa sustentable para la producción animal." Revista Argentina de Producción Animal, Suplemento 2015, 1-5. https://ri.conicet.gov.ar/bitstream/handle/11336/186376/CONICET_Digital_Nro.5ddcc3e0-224a-4396-a191-e2963f129f22_M.pdf?sequence=5&isAllowed=y

Rueff, L., Mellencamp, M., & Galina Pantoja, L. (2019). Performance of immunologically castrated pigs at a commercial demonstration farm over 3.5 years. *Journal of Swine Health and Production*, *27*(6), 322–328. https://doi.org/10.54846/jshap/1128

Squires, E. J., Bone, C., & Cameron, J. (2020). Pork Production with Entire Males: Directions for Control of Boar Taint. *Animals: An Open Access Journal from MDPI*, *10*(9), 1665. https://doi.org/10.3390/ani10091665

Van den Broeke, A., De Cuyper, C., Kress, K., Stefanski, V., Škrlep, M., Čandek-Potokar, M., Maribo, H., & Millet, S. (2022). The importance of pigs' castration strategy on carbon footprint of feed intake, nitrogen and phosphorus efficiency under different management conditions. animal, 16(12), 100669. https://doi.org/10.1016/j.animal.2022.100669

Yun, J., Ollila, A., Valros, A., Larenza-Menzies, P., Heinonen, M., Oliviero, C., & Peltoniemi, O. (2019). Behavioural alterations in piglets after surgical castration: Effects of analgesia and anaesthesia. *Research in Veterinary Science*, *125*, 36–42. https://doi.org/10.1016/j.rvsc.2019.05.009

Zamaratskaia, G., & Rasmussen, M. K. (2015). Immunocastration of Male Pigs – Situation Today. *Procedia Food Science*, *5*, 324–327. https://doi.org/10.1016/j.profoo.2015.09.064

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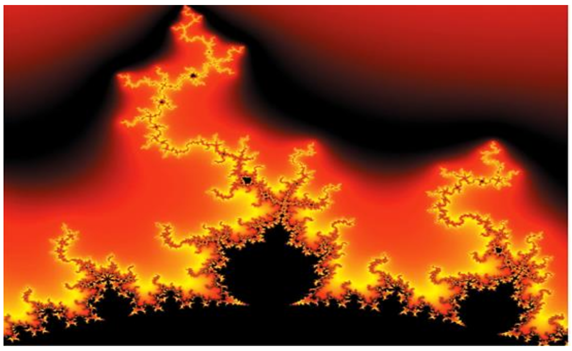

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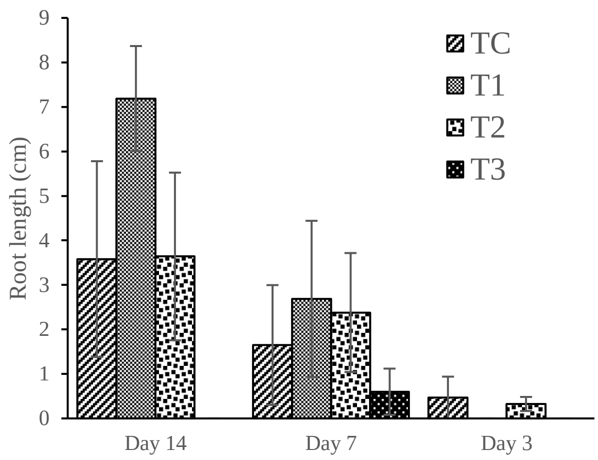


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